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16 ABSTRACT

The report lists and discusses new and existing equipment, materials, and practices available to prevent the entry of unwanted water into the sewer system from infiltration and inflow, and thereby needlessly usurping the capacity of the sewerage system.

The report has six sections covering:

1. A description of sewer cleaning techniques and equipment needed to help locate points of infiltration and inflow and to improve the accuracy of flow measurement.
2. A review of flow measurement equipment and techniques needed for a determination of the quantity of infiltration and inflow.
3. An examination of equipment and practices used to inspect the sewers and locate the entry points of unwanted water. This involves closed-circuit television, photographic inspection, low pressure air testing, and smoke inspection.
4. A discussion of current sewer grouting practices, equipment, and material, concentrating on the acrylamide gel and the elastomeric grouting compound.
5. A review of insertion pipe for rehabilitation, sewer fittings, and a brief discussion of trench backfilling monitored by nuclear soil-density meters.
6. An examination of safety practices that should be followed when crews undertake the task of controlling sewer infiltration and inflow.

The product and equipment guide and accompanying report and manual of practice were submitted in partial fulfillment of Grant No. 803151 between the U.S. Environmental Protection Agency and the American Public Works Association. Work was completed as of November, 1976.

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SEWER INFILTRATION AND INFLOW CONTROL PRODUCT AND EQUIPMENT GUIDE

By

William S. Foster
Richard H. Sullivan

American Public Works Association
Chicago, Illinois 60637

Grant No. 803151

Project Officer

Anthony N. Tafuri
Storm & Combined Sewer Section
Wastewater Research Division
Municipal Environmental Research Laboratory (Cincinnati)
Edison, New Jersey 08817

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components requires a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

Control of Infiltration/Inflow (I/I) has become a major early step in reducing the amount of untreated or poorly treated discharges of municipal sewage to receiving waters. This product and equipment guide has been presented to provide a ready reference for those concerned with identifying and controlling I/I.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

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A.E. Holcomb
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SECTION I

INTRODUCTION

The need to prevent infiltration of groundwater and other sources of unwanted water into a community's sewer system is well known and requires no documentation. However, one estimate can illustrate the negative impact of infiltration on the correction of the nation's water-pollution difficulties. Testimony at a Congressional Committee hearing estimated that these sources of unwanted water usurp at least 15 percent of the hydraulic capacity of the nation's sewerage systems.[1]

An estimate[2] of 460,000 miles (740,000 km) has been made as the total length of sewer used in communities of 2,500 or more. If 15 percent is inoperative because of infiltration and inflow (I/I), this amounts to 69,000 miles (111,000 km) of sewers, or about the same as all the sewers now in use in municipalities of 500,000 or more.

Collection Systems Neglected

While the collection system represents about 80 percent of the community's sewerage investment, those involved in this work have largely neglected it in favor of development of treatment techniques and similar studies. A recent review of the research literature compiled by the Water Pollution Control Federation showed that less than 3 percent of the review was devoted to wastewater collection.[3]

Scope of Survey

To respond to the need for more complete information on how this unnecessary I/I can be prevented, this review will survey equipment, materials, and techniques that will:

(1) clean sewers to clear away blockages.
(2) detect and measure the flow in sewers to help determine how much infiltration exists.
(3) inspect the condition of the sewers and test to see whether problems are evident.
(4) rehabilitate the system by grouting and other techniques.
(5) list pipe linings and fittings that can be used in new sewers, or as replacement for damaged portions of old lines.
(6) outline safety measures that should be followed when working in sewers and manholes.

Many have noted a complete change in the attitudes of designers and operators of sewerage systems toward infiltration and inflow. In the past, most were indifferent to this source of water, and some may have welcomed it. Today the policy is to prevent its entry insofar as it is economically possible.

The I/I detection and control area has developed rapidly and changes are occurring daily, resulting in products and practices becoming obsolete or outdated over a relatively short period.

This product and equipment guide is not a complete listing of all products or manufacturers who have products of use in I/I detection or correction, but rather lists the major suppliers identified during the course of the APWA study. Neither the USEPA nor APWA by reference in this report recommends or endorses the use of a particular item. Prices where given are those supplied to the APWA in the fall of 1975 and should be used only as an indication of the costs.

SECTION II

FLOW MEASUREMENT AND MONITORING

The investment in a sewer system is from three to four times that of the wastewater treatment facilities. Yet few governmental agencies have made detailed surveys of these flows or the conditions of the pipes and manholes in the system. Flow is routinely measured as it enters the treatment plant or pumping stations, but rarely is flow monitored in individual sections of the systems, except for casual inspections at manholes.

Monitoring in precise form is needed to help identify more accurately infiltration that usurps the capacity of the collection system and treatment works. It also is needed to calculate the reserve capacities of the various sections of the sewer systems, and to estimate their abilities to accommodate new loads.

Locating Infiltration-Prone Areas

The measurement of infiltration and inflow will be assisted by first determining where the groundwater levels are high enough to cause problems. One simple method of monitoring this level is to force a slotted pipe into the ground directly above the sewer, through the manhole wall. This pipe should be provided with an elbow, with a clear plastic pipe affixed to it, secured to the manhole wall, and extending vertically to an elevation above the anticipated groundwater level. The groundwater will then rise in the pipe and can be measured easily so that variations in the levels can be recorded. Figure 1 shows such a unit.

The weakness of this method is that the groundwater level at manholes may not be representative of levels elsewhere. So for greater precision, observation wells should be located between manholes in areas of critical concern.

For a quick location of infiltration and inflow areas, some have found the simple thermometer to be a useful tool. By noting a drop in the wastewater temperature, the investigator has evidence that cold infiltration water is entering the sewer.

Desirable Characteristics of Monitoring Equipment

In a study of sewer flows in Columbus, Ohio and elsewhere, the investigators listed the desirable characteristics of monitoring equipment:[4]

1. The equipment should make accurate flow measurements in sewers in wet and dry weather, including those sewers that surcharge.
2. It should be economical to purchase, install, and service.
3. It should be reasonably vandal-proof.
4. It should be reusable at other monitoring sites during the study.
5. It should maintain a minimum head loss through the measuring equipment to minimize unwanted effects on the hydraulic characteristics of the sewer.
6. It should be able to operate automatically for a minimum of 24 hours.

The equipment should also be rugged and dependable. Accurate equipment that requires a great deal of maintenance can present drawbacks to metering programs, especially in remote areas.

Measurement of Wastewater Levels

All flow-monitoring equipment for infiltration and inflow studies requires measuring the wastewater level over an extended period. This can be determined by any of several techniques.

Floats – The simplest of the measuring units. They can be spherical or cylindrical floats attached to appropriate measuring and recording devices often in a stilling well, or they may be the broad-based "scows" placed in the center of the channels. Both require attention because of the debris in the wastewater that can collect on them and interfere with their accuracy. Figures 2 and 3 show typical units.

Bubbler Tubes – Use a technique adapted from measurement of water levels in tanks. They require accurately regulated air or gas

pressures introduced through a tube at the bottoms of the channels, as shown in Figure 4.

Ultrasonics – An adaptation of sonar equipment to the measurement of wastewater levels offering the advantage of avoiding contact with the wastewater itself. Figures 5,6,7, show typical units.

Oscillating Probes – Have the advantage of not actually entering the wastewater. The measuring device lowers a probe at designated time intervals to the surface of the wastewater. When the probe makes contact, it completes a microampere circuit that causes the lowering motor to stop and retract slightly, permitting appropriate equipment to record this elevation. At a set time, the motor again lowers the probe and retracts it when it touches the wastewater level.

Capacitance Measuring Probe – Can measure and record wastewater level continuously through an electronic circuit. The probe may be mounted directly in the wastewater stream or in a stilling well. Figures 8 and 9 show typical units.

For a one-time measurement of velocity, Shelly and Kirkpatrick[3] suggest using an orange, since it floats partially submerged and therefore travels close to the mean stream velocity.

Flow Measurement Using the Pipe Dimension – Useful flow measurements, not to the greatest of precision, can be made by using the pipe itself as a means of measurement. Flow is determined by the simple but familiar formula, $Q = AV$. Calculations can be based on the height of the wastewater in the sewer and the measured velocity of the wastewater. It also can be based on the venerable but highly respected Manning formula.

To determine the velocity of the wastewater, the inspectors can use:

1. Floats, although they require continuous observation and offer no means of automatic measurement and recording.
2. Dyes, of potassium permanganate, fluorescein, or rhodamine, however they also require the presence of an inspector to note when the center of the mass of colored liquid passes, and poses the uncertainty of whether the observed dye-cloud is the mean or surface velocity.
3. Salts and radioactive tracers, both adaptable to equipment that permits automatic measurement and recording over an extended period.
4. Self-cleaning vanes, movable but set at an angle to the flow by a calibrated resisting force; the degree to which the flow in the sewer overcomes this force measures velocity, also adaptable to recording equipment.

Salt Solution – Inspector places two pairs of electrodes in the stream at a known distance apart, and energizes them with an electrical current to measure velocity. The electrodes can then signal the passage of the introduced salt solution by a recording galvanometer. By introducing the salt solution at controlled intervals, the equipment can measure the velocity over a suitable period of time. The salt solution can be used to measure velocities at accuracies of better than ±2 percent.

Radioactive tracers – Provide equally precise measurements; however, many dislike placing radioactive material in wastewater.

The Manning Formula – Inspector selects a length of pipe that is smooth and provides nonturbulent upstream conditions for 200 ft (60 m). The course should be free of abrupt dips, sudden contraction or expansions, and tributary inflows.

The Manning formula requires a determination of the slope of the water surface, rather than the pipe itself. It also requires an estimate of the roughness factor, generally assumed to be $n = 0.013$ for pipe in good condition, in use; however, this can be only an approximation at best.

Flumes for Flow Measurement

Parshall-type flumes improve the accuracy of measurement substantially. They have good range and accuracy, and are only slightly affected by changes in flow. Solids in the wastewater do not interfere materially. The flumes are rugged, retain their calibration, and are easily portable. They create only a slight obstruction in the flow and require very little operator attendance.

Of these flumes, the Palmer-Bowlus type as shown in Figure 8 has demonstrated accuracies of 97 percent of theoretical rating

at depths as great as 90 percent of the pipe diameter. The flume has a round bottom shape which permits it to be mounted easily in the pipe invert. The flume can be sealed to the invert section using mastic. It can be held firmly in position with a sandbag or other weight.

The Palmer-Bowlus flume should have a minimum throat length of one pipe diameter, but in no case less than 60 percent of the pipe diameter. The point of upstream depth measurement should be no more than half the pipe diameter upstream from the entrance to the flume. The approach sewer should have a slope of no more than 2 percent.

The Palmer-Bowlus flume originally was designed in several pieces that could be put into a pipe of any given diameter, but this arrangement required field calibration at each new point of installation. The flumes now can be obtained in prefabricated precalibrated form for a given pipe diameter.

The Leopold-Lagco flume is somewhat similar to the Palmer-Bowlus, but incorporates important differences. It has a true rectangular throat section throughout the entire flow range while the throat of the Palmer-Bowlus is trapezoidal at the bottom and rectangular at the top.

Weirs for Flow Measurement

Weirs also offer precision in measuring and recording wastewater flows; however, a weir restricts the capacity of the sewer. The most common weir shape for this type of work is the V-notch using a 90° angle. It can measure flows of 1 cfs (28.3 l/s) or less, and is as accurate as any other weir profile. Flows as high as 10 cfs (283 l/s); however, head requirements at these higher flows may rule them out. Other common types are the rectangular and the trapezoidal, or Cipolletti weirs. Figures 10 and 11 show two types of available units.

Weirs for this work should meet these general requirements:

1. Have a smooth upstream face that is perpendicular to the vertical and horizontal axes of the channel.
2. Be installed so that the crest will be at least 1 ft (30 cm) above the approach channel bottom where pipe size permits, and the minimum head will be at least 0.2 ft (6 cm).
3. Have a thickness not exceeding 0.125 in. (0.3 cm).
4. The cross-sectional area of the approach channel should be at least eight times that of the nappe at the crest for an upstream distance of 15 to 20 times the height of the crest.
5. The crest should be thin, preferably beveled with the sharp edge upstream; installed so that the wastewater being measured will not contact the weir structure downstream but spring past it.
6. The minimum height of the weir crest should be at least two and preferably three times the maximum head expected over the weir.
7. When the water level under the nappe rises above the weir crest, the flow may be considered submerged. To determine the rate of flow under such submerged conditions, both the upstream and downstream heads must be measured and reference made to submerged flow tables.
8. To avoid the effects of "drawdown" as the flow passes over the weir, the gauging point should be located upstream of the weir crest a distance of at least three and preferably four times the maximum head expected over the weir. A minimum of 18 in. (46 cm) is generally used.

Weirs can be constructed "in shop" if the construction is precise and the accuracy of the measurement checked. However, prefabricated V-notch weirs are commercially available with calibrations that permit direct flow readings.

Successful fabrication of a weir requires use of aluminum or stainless steel mounted on marine plywood, using nonferrous screws and a gasket. The edges should extend at least 1 in. (2.5 cm) above the edges of the plywood to insure a sharp edge to the notch as the wastewater flows through it. The weir-supporting bulkhead should be precisely braced and anchored in place, sealed with mastic to insure that all the flow will pass over the V-notch.

Safety in Installation and Operation

Since the installation of the equipment requires the entry into the manhole by personnel, pre-inspection of the manhole for explosive gases is mandatory, as well as safety harnesses and other equipment. For a detailed discussion of safety practices, see Section VII.

Principal Suppliers of Flow Measuring/Monitoring Equipment

Wastewater Level Recorders

American Chain and Cable Company, Inc., ACCO Bristol Division, Waterbury, Connecticut 06720. Produces the Bristol Series 840 L/V (level and velocity) Monitoring System for use in large sewers from 4 to 20 ft (1.2 to 6.1 m) in diameter. It is portable, and designed for use in manholes.

The unit measures velocity by a drag-type primary element in the probe assembly. As the moving stream impinges on the target area of the element, its impact force causes a linear deflection which is detected by a strain gauge bridge and recorded electronically in the Probe/Controls cabinet.

The level-sensing device in the probe operates through an air-bubbler principle. The probe has a self-cleaning feature that operates at 15-minute intervals.

The manufacturer reports a range of velocity measurement of 0 to 10 ft/s (0 to 3 m/s) with an accuracy range of ±5 percent. The liquid-level ranges from 8 in. (20 cm) to full conduit with an accuracy of ±0.25 in. (0.64 cm).

A typical assembly for a 5 ft (1.52 m) sewer will weigh 300 lbs (136 kg).

Badger Meter, Inc., Precision Products Division, 6116 East 15th Street, Tulsa, Oklahoma 74115. Manufactures the ML-MN transmitter designed for open-channel flow head measurement. A float placed in the wastewater stream determines the level which is transmitted and recorded on an electronic receiver, Badger's 2700 series.

The float assembly should have frequent inspections since it risks the possibility of fouling or damage from material in the wastewater.

Badger also produces the models UH 200 and UH 210 ultrasonic flow transmitters which measure liquid levels in flumes, weirs, sewers, or other open or partially full channels. A sonic probe makes the measurement by transmitting sonic energy to the fluid surface and measuring the elapsed time for the reflected energy to return. The UH 210 transmitter converts the level signal to any specified depth-flow relationship required. The transmitters can be installed with relative ease in new and existing locations. The transmitter must be at least 6 in. (15 cm) above the maximum liquid level. Accuracy is within 2 percent.

Corning Laboratories, Inc., P.O. Box 625, Cedar Falls, Iowa 50613. Manufactures the Corning AquaRecorder for sensing and recording water-level fluctuations. When installed in a manhole, the unit will electronically sense water levels at preset time intervals and record data for as long as three weeks on one cassette tape. The tape then can be played back and data sequentially flashed on the screen of a digital readout, eliminating the need for charts and pens.

The instrument is designed to measure water depths to an accuracy of 0.1 in. (0.25 cm). It is self-contained, operates with a 6-volt battery, with electrical circuitry and components in the upper control unit, out of danger from wastewater surcharge, and protected from damage in case of fall by a styrofoam liner.

The sensing probe is automatically lowered from its housing at preset time intervals by being lowered through a stilling well. When it touches water, it automatically stops, records the elevation, and retracts. It can be "backed" out if accidentally submerged, and returned to working order.

Its current price is $975.00 f.o.b. Cedar Falls, Iowa.

Drexelbrook Engineering Co., 205 Keith Valley Road, Horsham, Pennsylvania 19044. Manufactures flow gauges for use with weirs, flumes, nozzles, and pipe channels. It makes use of a sensing element with no moving parts, described as a precision admittance-to-current transducer. A variation in liquid levels will cause minute amounts of current to flow from the sensing probe to the grounded stream. A compensated bridge circuit measures this change in current to an accuracy of ±0.5 percent. The probe

immersion depth can vary from 12 in. (30.5 cm) to 36 in. (91.5 cm).

In the Series 508 models, the system will ignore build-up on the sensing element which can be expected when used in wastewater. For direct, instream use, an optional tilt-away mounting is available. With it, the probe is held by an adjustable counterweight but is free to pivot out of the way when struck by an object in the flow. It also will tilt to clean if the probe collects fibrous materials such as rags, paper, and similar material.

Current prices of the Series 508 systems range from $553.00 to $1,371.00 depending upon immersion span and type of indicating meter used.

Ours, Inc., P.O. Box 3816, Orlando, Florida 32803. Manufactures the Q-Flow Surveyor which measures the level of flow in the sewer by sensing the level of the wastewater surface. The probe does not enter the surface but maintains a position directly above it. A 24-hour or a 7-day chart records this level.

A three-legged set of clamps permits installing the Surveyor in the manhole at street level. Installation time is reported to be 15 minutes.

Q-Flow Surveyors can be supplied in three sizes for use in sewers with diameters from 4 to 120 in. (10 to 315 cm).

Environmental Measurement Systems, Division of Wesmar, 905 Dexter Avenue North, Seattle, Washington 98109. Supplies the noncontact Ultrasonic Flow Monitor UFM-200 and the portable noncontact Ultrasonic Manhole Monitor UMM-12.

The UMM-12 was designed specifically for manhole application. It is a portable, battery-operated unit employing a noncontact, ultrasonic sensor to measure the wastewater level. A digital span dial, which allows dialing in of pipe sizes from 3 in. (7.5 cm) to 100 in. (2.5 m), automatically programs the device to measure that size. The dial is set in increments of 0.1 in. (0.25 cm). The measured and calculated data appear on a strip chart. The UMM-12 can operate up to 14 days on one battery charge.

The noncontact Ultrasonic Flow Monitor UFM-200 permanently records liquid flow through a weir or flume on an inkless strip chart and a five-digit totalizer. A visual linear readout meter indicates gallons per minute. The unit is factory calibrated to the particular flume (flow curve) or pipe size for which it will be used. Calibration can be easily changed in the field. The UFM-200 can be adapted to battery operation. Accuracy of 1 percent at any point on the scale is ensured.

Fitzgerald Engineering Company, Inc., 2601 Southwest 69th Court, Miami, Florida 33155. Manufactures the Fitzgerald Flow Measuring Device to determine the elevation of the invert, the depth of flow, and the amount of solids above the invert. Accuracy is stated as generally 90 percent of the volumetric flow. Determination can be made within 5 minutes per reading.

Leupold & Stevens, Inc., P.O. Box 688, Beaverton, Oregon 97005. Manufactures three float operated flow measuring instruments. Models 61M and 61R flow meters and Type F recorder, plus a line of staff gauges.

The Model 61R flow meter can be used with any type of weir or flume by a simple in-field change of flow cam and gears. It will record from a range as small as 14,000 gal/d (53 m^3/d) up to extremely large flows. Both English and metric measurements are available. A standard 50 ft (15.2 m) strip chart provides continuous recording from 30 to 180 days. An 8-day spring drive clock or AC synchronous motor provides power for the chart drive and seven-digit totalizer. Optional accessories include a sampler switch, a chlorinator pacing potentiometer, adjustable controls for auxiliary equipment or alarms, and a weatherproof enclosure.

The Model 61M flow meter has an indicator in place of the chart, otherwise it has the same features as the Model 61R.

The Type F recorder is a water level recorder with several styles of charts available. Two of the charts will record flow, one from Parshall flumes and one from V-notch weirs. An automatic clock starter accessory permits the instrument to sit dormant until a predetermined level is reached whereupon it will begin recording. It will record from four hours up to eight days and is available with several clock drives and a wide range of gears.

Current prices range from around $415.00 for the Type F up to around

$850.00 for the Model 618, depending upon various options.

Manning Environmental Corp., P.O. Box 1156, Santa Cruz, California 95061. Produces the Manning L-2000 and L-3000 series "Dipper" liquid-level recorders. Both consist of a control module that lowers a thin, noncorrosive probe on a weighted wire. When the probe contacts the water surface, it completes a microampere circuit through the conductive liquid to a ground return. This causes the motor in the control module to reverse its direction and raise the probe above the surface for the next cycle. The manufacturer reports liquid-level accuracies of 0.01 ft (3.28 mm). With special attachments it can operate at 25 ft (7.6 m) above the flow, or in manholes with offset channels. The liquid levels are recorded on a chart powered by a spring-wound clock mechanism that can be set for 7 days or for 24 hours.

Major features of the L-2000 series include:

1. Completely hermetically sealed package which is rated to withstand surcharges of 1 ft (30 cm) of water above the top of the case for at least two hours.
2. Built-in desiccator to absorb internal condensation.
3. Charts and recording interchangeable with existing Dippers, usable with existing manhole brackets, etc.
4. An external cable winding assembly which is readily visible and easy to maintain.
5. Hermetically sealed cable slack switches and up stop switches, easily adjusted.
6. An optional clear plastic cover which allows the operation of the equipment to be visible without opening the meter.

The L-2000 series provides recording of liquid level only, with models covering ranges of 15, 30, 60, and 120 in. (38, 76, 152, and 305 cm). The L-3000 provides a recording of flow rate and totalized flow when used with weirs, flumes, or round pipes. In addition, it can actuate a sampler in a flow-proportional basis. Various models can measure over ranges up to 24, 48, and 120 in. (0.61, 1.26, and 3.05 m). An important feature is that it can record overages in case of surcharge and go back to its original measuring point after the surcharge.

A special bracket allows the unit to be mounted just below street level under the manhole cover. With the use of a Depth Calibration Gauge, the initial calibration can be done from the top of the manhole without entry.

Current prices of the L-2000 series vary from $1,075.00 to $1,250.00, plus accessories. Prices of the L-3000 series vary from $1,435.00 to $1,570.00, plus accessories.

Manning also produces an ultrasonic flowmeter, the UFC-2000 Level Sounder and Flow Computer. The equipment is built to offer flow totalization, flow proportional sampling output, level indication, and flow recording on a 30-day strip chart. The manufacturer states that it can provide a head-to-flow conversion accuracy of better than 0.4 percent with an overall accuracy of 1 percent. The price of the total package is in the range of $2,000.00.

Martig Bub-L-Air, 2116 Lakemoore Drive, Olympia, Washington 98502. Supplies four models of Bub-L-Air sewer flow monitors with special sensing probes for pipe diameters ranging from 4 to 30 in. (10 to 76 cm). Model 1 records flow in sewers not subject to surcharge. Model 2 records flow in sewers subject to surcharge to 12.5 ft (3.8 m) and will also record groundwater levels outside the manhole. Model 3 will record simultaneous flows from two sewer lines entering one manhole. It also can record flows through a single sewer line, and intermittent flows into the manhole, such as catch-basin inflow or discharge from a pumping station force main. Model 4 is a custom designed package for special applications.

The sensing tube of the Bub-L-Air is installed in the upstream sewer line secured at the entrance to the manhole by a stainless steel strap. The recorder and air bottle can be hung to the manhole ladder, or on a 2 x 4 in. (5 x 10 cm) board braced within the manhole. It can be placed on the manhole floor ledge if no sewage surcharge is anticipated.

Manufacturer states that the monitor will record direct linear depth readings from 0.25

to 30 in. (0.63 to 76.2 cm) with an accuracy of 0.125 in. (3.18 mm), and also emphasizes portability, light weight, compactness, and speed of installation from 6 to 7 minutes.

Current prices for the monitors, including probes for 8 to 12 in. (20 to 30 cm) pipe usable in sewers of 4 in. (10 cm) diameter and larger are: Model 1, $1,197.00; Models 2 and 3, $1,497.00. No prices listed for Model 4.

NB Products, Inc., 35 Beulah Road, New Britain, Pennsylvania 18901. Produces the Series F and Series H manhole meters for use on pipes from 8 to 48 in. (20 to 122 cm).

The Series F is a portable device consisting of a transducer equipped with a telescoping support and a screw-shaped float, and an instrument case containing a control box and a strip chart recorder. A sensing unit inside the transducer determines changes in the level of water by measuring the float arm's angle of inclination. The recorder can run for 30 days.

The Series H manhole meter totalizes the flow and records elevations on a 30-day strip chart, and is distinctive in that it is programmed to account for variations in the Manning "n" number. Both should be adaptable to use with a measuring flume or weir. Both the F and H models are available for rental.

N-Con Systems Company, Inc., 308 Main Street, New Rochelle, New York 10801. Supplies the surface tracking level recorder designed to measure and record wastewater levels in sewer mains without the need for personnel to enter the manhole. Uses an adjustable mounting bracket that supports the recorder on the lip of the manhole immediately under the cover. A dual contact probe lowers until it touches the surface and then retracts 0.125 in. (0.32 cm). A rising wastewater level causes the probe to retract immediately until it loses contact with the wastewater.

It is available in three interchangeable ranges: 0 to 15 in. (0 to 38 cm); 0 to 30 in. (0 to 76 cm); and 0 to 60 in. (0 to 152 cm). The Surfer employs a dual traverse recording system to double the recording range during surcharges without loss of record or shifting of the zero setting. Circular charts permit one-day or seven-day recording.

Tracking interval is 10 seconds. Power requirements are 12-volt DC which can be supplied by a 10 amp/hr rechargeable battery, available with the unit. It can operate at a maximum of 35 ft (7.6 m) above the wastewater surface and can be used either with a flume or weir for precise measurements of flow.

Robertshaw Controls Co., Industrial Instrumentation Division, P.O. Box 26544, Richmond, Virginia 23261. Produces the level-Tel transmitter model 157 which appears applicable to manhole installation along with the model 735 probe. The probe will measure head level on primary devices such as weirs and Parshall flumes. It can be installed directly in the streamflow for fast response, or in stilling wells. The probe characterization is accomplished by varying the effective plate area and by maintaining a constant insulation thickness. The transmitter can be mounted directly on the probe. A variety of recorders and totalizers can be used with the probe and transmitter.

Sigamotor, Inc., 14 Elizabeth Street, Middleport, New York 14105. Supplies the Sigamotor LMS-400 battery operated meter that measures the level by the bubbler principle. Designed for use in manholes to measure wastewater levels in the open channel, or at flumes or weirs. It weighs either 18 or 35 lbs (8.2 or 15.9 kg), depending on the battery selected (it can be powered by 115-volt AC or 12-volt DC).

Its size is 13 x 14 in. (33 x 36 cm) by 10 in. (25 cm) deep. It is equipped with a 31-day pressure-sensitive strip chart and a six-digit totalizer.

Tri-Aid Sciences, Inc., 161 Norris Drive, Rochester, New York 14610. Manufactures the Tri-Aid ultrasonic noncontacting flow meter, totalizer, and transmitter instruments for measuring wastewater flows in open channels with or without a flume or weir. The small corrosion resistant, explosion proof, ultrasonic transducer is for bracket mounting from a 0.75 in. (1.9 cm) conduit above the wastewater flow. The electronic measurement system may be mounted up to 500 ft (152.4 m) from the point of flow measurement. Automatic temperature compensation is standard on all units. The highly accurate

instruments read out directly in flow rate, provide totalized flow and may control flow proportional sampling. Field calibration of the instruments is accomplished without the use of external test equipment.

UES Universal Engineered Systems, Inc., 7071 Commerce Circle, Pleasanton, California 94566. Manufactures five flow monitor models. Each Flo/Monitor is manufactured for specific applications. Model 8090 is for 120V-60Hz use. Model 8091 uses a rechargeable gel battery and is provided for applications where 120V power is not available. Model 8092 is manufactured for remote operation. It includes a remote transmitter, located near the flume, which transmits data to the Flo/Monitor over distances up to 2,000 ft (610 m). All three of these Flo/Monitors will accept UES Palmer-Bowlus flumes, sizes 4 to 15 in. (10 to 38 cm), without any calibration by the owner.

The UES 8097 Flo/Monitor is manufactured for applications with Palmer-Bowlus flumes larger than 15 in. (38 cm), all sizes of Parshall flumes, weirs, and Venturi tubes. This model is programmed by the factory for the specific primary use. It utilizes sensors such as capacitance pressure sensors, pressure transducers, differential pressure transducers, and float operated transducers. This 120V-60Hz model gives a 4-20 mA signal to pace samplers, chlorinators, and other assorted extras.

The 8098 Flo/Monitor has the same electronics as the 8097 and is equipped with a remote transmitter for remote operation up to a distance of 2,000 ft (610 m).

UES states a ±4 percent accuracy for all of the Flo/Monitors listed above. Each instrument contains a six-digit totalizer and a 30-day strip chart recorder. Circular chart recorders are available by special order. These solid state Flo/Monitors contain no moving parts other than the totalizer and recorder. Prices range from $1,580.00 to $1,980.00.

Measuring Flumes and Weirs

Badger Meter, Inc., Precision Products Division, 6116 East 15th Street, Tulsa, Oklahoma 74115. Manufactures a measuring flume designated the Manhole Meter. The unit can be inserted through a 20 in. (51 cm) diameter manhole opening and is produced in 6, 8, 10, and 12 in. (15, 20, 25, and 30 cm) diameters. The manhole is used as the stilling well. Self-cleansing flows are reported and accuracy is reported as ±2 percent.

Flume Company, P.O. Box 575, Westfield, New Jersey 07091. Manufactures three-piece flumes of cast iron, keyed sections designed to a venturi form that will fit a circular pipe or U-channels, often without sealing; however, the manufacturer states that if the joints are easily sealed. Flumes are designed to fit pipes with diameters varying from 6 through 30 in. (15 through 76 cm). Manufacturer recommends screw floats and Leupold & Stevens Model 61R flow meter, however, most of the equipment that measures wastewater levels previously listed should be able to work with this flume.

Manufacturer states that the flume must be used in sewers producing less than "critical" velocities; a table in the manufacturer's literature gives appropriate information.

Hinde Engineering Company of California, P.O. Box 56, Saratoga, California 95070. Manufacturers "Accuro-Flo" insert flume generally of the Palmer-Bowlus type. It is made of stainless steel, and is a one-piece unit. Within the normal range of flows, less than 10 to as large as 90 percent of pipe capacity, the accuracy is reported to be within 3 percent. Sizes range from 6 through 27 in. (15 through 69 cm) in diameter. Maximum recommended slopes, from the smallest diameter to the largest, vary from 2.2 to 1.3 percent. Similarly, the flume's maximum flow capacities vary from 0.35 to 14.7 cfs (9.9 to 416 l/s). To measure the wastewater levels with on-site recorders, the manufacturer reported that floats with stilling wells, screw floats, and bubbler systems have been used successfully.

F. B. Leopold Company, Division of Sybron Corporation, 227 South Division Street, Zelienople, Pennsylvania 16063. Manufactures the Leopold-Lagco flumes made in a rectangular cross section and moulded of a fiberglass laminate with the company name of Leo-Lite. The flumes can be installed directly in the sewer line, normally at a standard straight-through manhol... The most suitable type for I/I studies is the "insert"

which can be placed in an existing half section of pipe. The "cutback" type can be used where space is critical. The manufacturer reports accuracy to ±3 percent. Sizes range from 6 in. (15 cm) to 6 ft (1.8 m). Flow capacities range from 0.25 cfs (7.1 l/s) to 177.7 cfs (5032 l/s). Prices range from $300.00 to over $3,000.00.

Manning Environmental Corp., P.O. Box 1356, Santa Cruz, California 95061. Company offers several Palmer-Bowlus flume designs. The quick-insert flumes can be installed in any size pipe or manhole invert. The more permanent flumes will require grouting into place. The manufacturer states that the flumes can measure flow in depths of 95 percent of the pipe diameter within accuracies of 3 percent. The Palmer-Bowlus flumes are produced in diameters of 30 in. (76 cm) with larger sizes available on request. End bulkheads can be installed to match the smaller flumes to larger channel shapes.

NB Products, Inc., 35 Beulah Road, New Britain, Pennsylvania 18901. Produces portable V-notch weirs in several sizes specifically designed to measure sewer infiltration. Adapters are provided so that the weirs can be installed in sewers with diameters to 42 in. (107 cm). They are made of weather-resistant aluminum. The dial face is cut from transparent plastic and calibrated for direct readings in gallons per 24 hours. Individual weirs can be supplied for sizes to 15 in. (38 cm). The adapters are supplied to fit the 15 in. (38 cm) weir to the larger sizes.

Plasti-Fab, Inc., P.O. Box 227, Tualatin, Oregon 97062. The company manufactures fiberglass Parshall flumes in a variety of sizes 1 in. (2.5 cm) and larger. It also produces Palmer-Bowlus flumes and "cutback" flumes in fiberglass and stainless steel, as well as fiberglass H-flumes for measuring wide ranges of flow varying as much as 100:1. Also available are fiberglass trapezoidal and cutthroat flumes. All flumes can be provided with accessories such as attached floatwells, bubble pipes, cavities and supports for capacitance probes, and mounts for sonic transducers.

Polcon, Inc., 8050 Watson Road, St. Louis, Missouri 63119. Supplies the Polcon portable sewer meter consisting of a PVC tube in diameters from 8 through 15 in. (20 through 38 cm). The tube is made in 12 in. (30 cm) segments for insertion at the manhole into the downstream sewer and clamped together. A bubbler system measures flow depth and a portable instrument assembly records flow data. Slope of the tube must be determined within 0.1 percent and normal operating range is between 0.3 to 5.0 percent.

Several types of units are available. The Polcon DAF instrument is a self contained air/bubble unit. Electrical power and compressed air are needed from separate sources. Four self contained units are available. Model P.I.P. 100 requires a separate air source and a spring wound recorder. The P.I.P. 101 is supplied for use with a bottle of CO_2, for 14 day use. The P.I.P. 102 has a 1/12 H.P. air compressor and an electrically driven recorder. The P.I.P. 112 combines both the bottle CO_2 and the air compressor to avoid failure in the event of a power failure.

Robertshaw Controls Co., 1701 Byrd Avenue, Richmond, Virginia 23226. Supplies the Free-Flow Parshall Fume constructed of polyester-reinforced fiberglass with satin stain finish on all surfaces exposed to flow. Flume is manufactured by Free Flow, Inc., P.O. Box 4067 Benson Station, Omaha, Nebraska 68104.

Flume reportedly can be adapted to manhole use. It is equipped with a stilling well and a capacitance sensing system to measure and record wastewater levels on a continuous basis.

UES Universal Engineered Systems, Inc., 7071 Commerce Circle, Pleasanton, California 94566. Manufactures measuring flumes utilizing the Palmer-Bowlus formula. Measuring flumes are plastic and incorporate the use of a capacitance pressure sensor (CPS) that utilizes a captive liquid to separate the sensing element from the flowing stream. This feature allows measurements to be unaffected by build-up or coatings from the flowing stream. UES also manufactures Parshall flumes that utilize the CPS straight sensor.

The UES Palmer-Bowlus flumes, sizes 4 to 15 in. (10 to 38 cm), are made primarily to work in conjunction with models 8090, 8091, and 8092 UES Flo/Monitors. Sizes larger than 15 in. (38 cm) and Parshall flumes are used in

conjunction with models 8097 and 8098 Flo/Monitors. UES also manufactures weirs by special order and programs the 8097 or 8098 to the specific weir. Venturi tubes, utilized with the 8097 or 8098 Flo/Monitor, are also manufactured to be used in closed pipe with various liquids and solids-bearing liquids.

Prices for the standard 4 to 15 in. (10 to 38 cm) Palmer-Bowlus flumes range from $170.00 to $476.00. Larger Palmer-Bowlus flume, Parshall flume, weir, and Venturi tube prices are available upon request.

Velocity Meters and Dyes for Velocity Measurements

American Chain and Cable Company, Inc. ACCO Bristol Division, Waterbury, Connecticut 06720. The Bristol series 840 L/V monitoring system measures both wastewater level and velocity of wastewater in sewers with diameters of 4 ft (1.2 m) or more, and is designed for use in existing manholes.

The system measures velocity by a drag-type primary element in the probe assembly, and is equipped with strain gauges. The moving stream deflects the element; the deflection is measured by the strain gauges and translated into velocities. Velocity range is from 0 to 10 ft/s (0 to 3 m/s) with accuracies of ±5 percent.

Badger Meter, Inc., Precision Products Division, 6116 East 15th Street, Tulsa, Oklahoma 74115. Produces the Badger Model UF 110A open channel, ultrasonic flowmeter designed to measure flow in sewers, flumes, and other types of open or partially filled channels. A pair of ultrasonic velocity probes, one on each side of the channel and submerged, measures the velocity while an ultrasonic depth gauge measures flow depth. The manufacturer states that the instrument can be installed in new or existing locations with relative ease, and results in essentially obstructionless flow with little or no head loss.

Chem, Inc., P.O. Box 9516, Orlando, Florida 32809. Provides fluorescent tracer dyes in fluorescent yellow and red in 1 and 5 lb (0.5 and 2.3 kg) packages.

Formulabs Fluorescent Dye Tracing Systems Division, P.O. Box 1056, Escondido, California 92025. Supplies fluorescent dyes in a variety of solid forms: tablets 0.08 oz (2.3 gm), cakes 1.90 oz (53.9 gm), donuts 11.6 to 41.2 oz (0.33 to 1.17 kg), and logs in diameters of 3 in. (7.6 cm) and lengths to 4 ft (1.2 m) and weighing 18.9 lb (8.6 kg). Dyes are reported nontoxic in red and yellow colors designed to produce distinguishable colors in concentrations of 1 mg/l.

Current prices are:

tablets	$0.07 each (3,600 minimum)
cakes	$1.11 each
cones	$4.39 each, 3 oz (85 gm);
	$2.49 each, 6 oz (170 gm)
donuts (small)	$4.15 each, red;
3 in. (7.6 cm)	$3.90 each, yellow
donuts (large)	$15.00 each, red;
4 in. (10.2 cm)	$11.20 each, yellow
logs 4 ft (1.2 m)	$96.06 each
liquid concen	$14.65 per gal
trate	($3.87 per l)

Kahl Scientific Instrument Corp., P.O. Box 1166, El Cajon, California 92022. Can supply fluorescent dyes in either red or yellow-green colors. When used in a sewer, the dye will last for several days. Provides tablets with diameters of 0.75 in. (2.20 cm) in packages of 100 per bottle. One tablet will provide a concentration of one part per billion in 0.2 gal. (0.45 m^3). Larger dye cubes also are available but are designed for oceanographic studies.

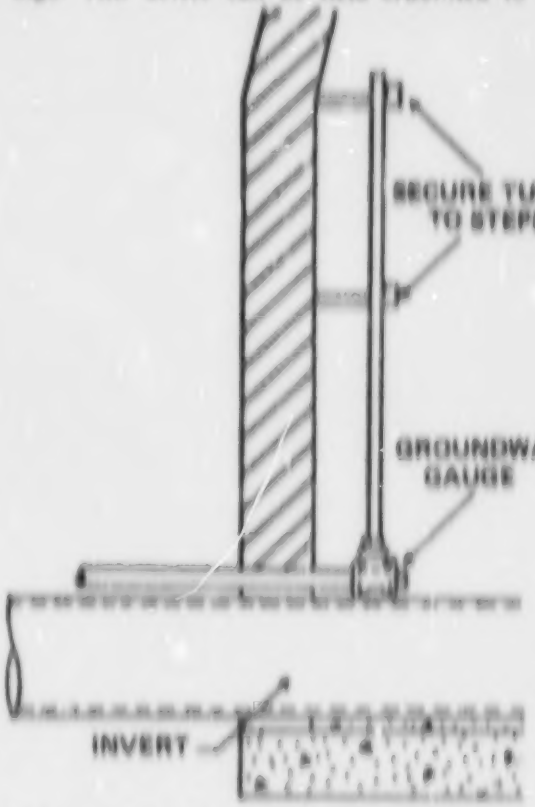
Marsh-McBirney, Inc., 2251 Lewis Avenue, Rockville, Maryland 20851. Produces the Marsh-McBirney Model 201 portable current meter powered by standard D-size batteries. The meter is calibrated in three switchable ranges: 0-2.5 ft/s (0-47 cm/s), 0-5 ft/s (0-152 cm/s), and 0-10 ft/s (0-304 cm/s). Accuracy is reported at 0.05 ft/sec (0.015 m/sec). The meter must be held by the operator and can provide a quick check on Manning flow calculations.

The current velocity is measured by an electromagnetic sensor. No moving mechanical equipment is involved. The price is $1,150.00.

The Model 250 sewer flowmeter combines measurements of level and water velocity into flow. The same basic electronic velocity sensor as used in the Model 201 has been reconfigured to fit in the bottom of a pipe and has been streamlined so

as not to collect debris. Additionally, a bubble device has been included in the transducer.

The level information obtained from the bubble gauge and the velocity information obtained from the electromagnetic sensor are combined in a signal processor so as to yield a single output that is a measure of the flow in mgd. This device can be field calibrated to accuracies better than 5 percent of average flow and is unaffected by blockages downstream in the sewer that cause the water level to rise and the velocity to slow down. No knowledge of the slope or roughness factor of the pipe is necessary. In addition, the device also operates in filled pipes and will give correct readings even during sewer surcharges. Prices start at $1,950.00.



Source: American Pipe Services, Minneapolis, Minnesota

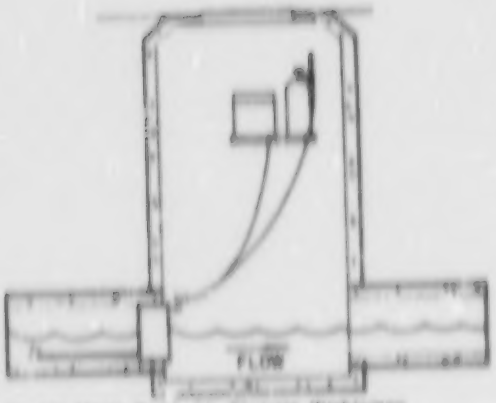
Figure 1. Groundwater Gauge

Source: NB Products, Inc., New Britain, Pennsylvania

Figure 2. The NB Products recording unit in a manhole. Note the screw-type float used to measure liquid levels.

Source: Leupold & Stevens, Inc., Beaverton, Oregon

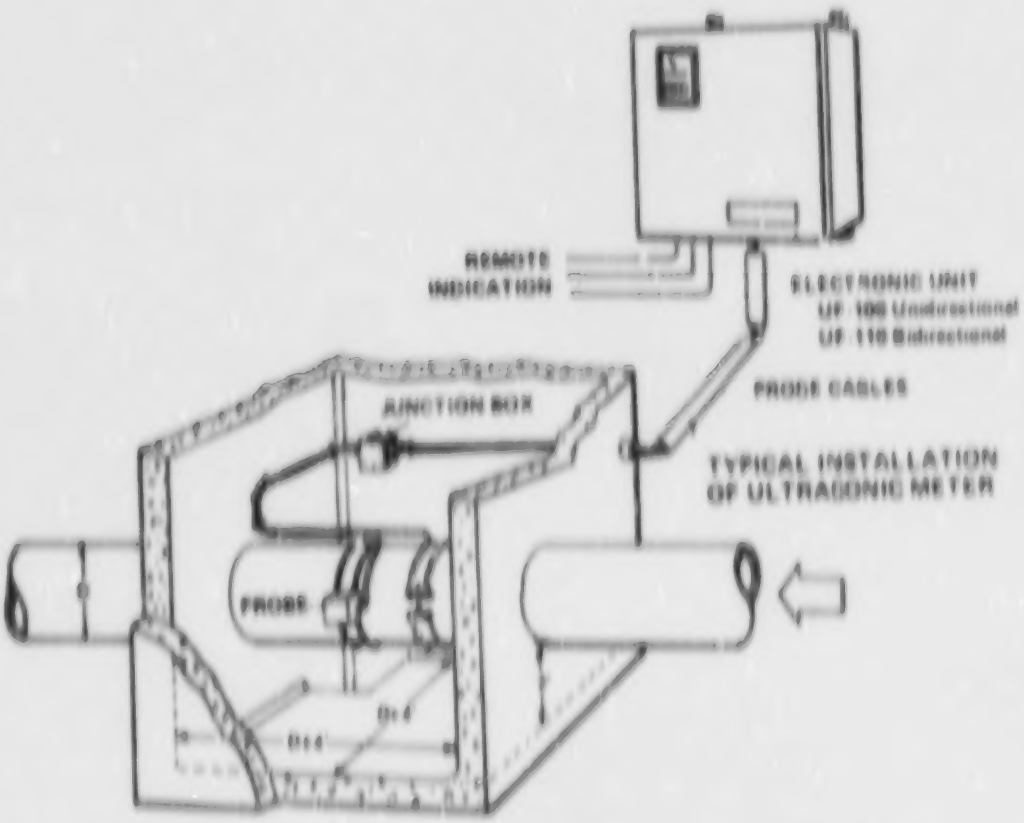
Figure 3. A Leupold & Stevens model 61R recorder used in a manhole installation with a screw float.



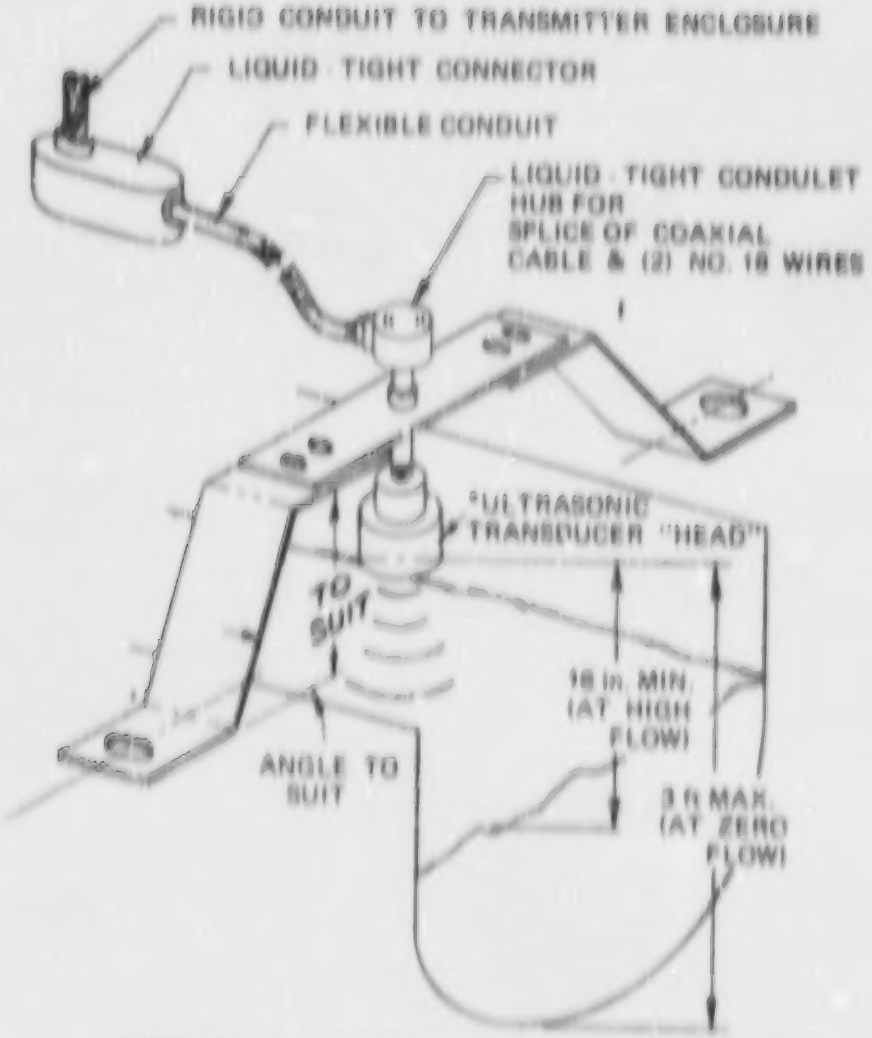
Source: Martig Bub-L-Air, Olympia, Washington

Figure 4. The Martig Bub-L-Air system in place, measuring the wastewater level in the inlet pipe. The same system can be used with flumes or weirs.

Figure 5. The Badger Meter sonic flowmeter measures both velocity and waste water level.



Source: Badger Meter, Inc., Tulsa, Oklahoma

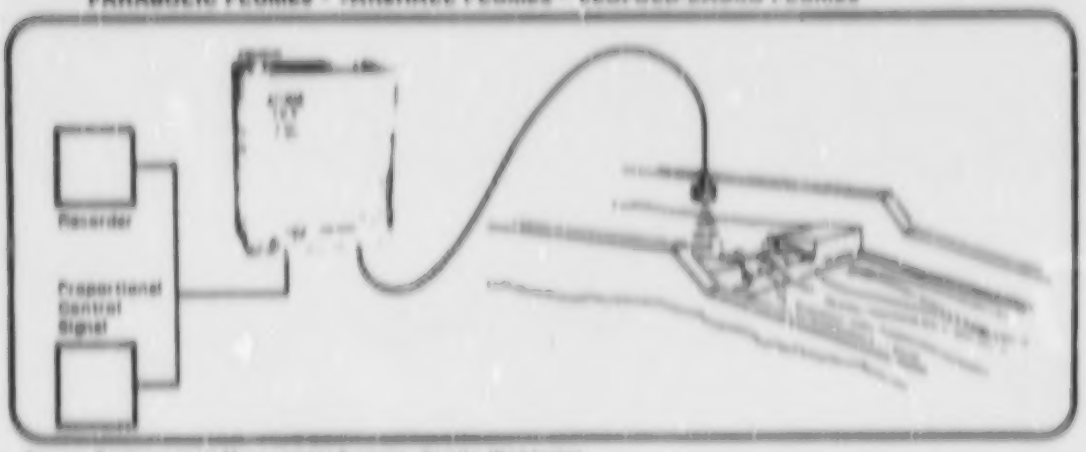

RIGID CONDUIT TO TRANSMITTER ENCLOSURE
LIQUID - TIGHT CONNECTOR
FLEXIBLE CONDUIT
LIQUID - TIGHT CONDULET HUB FOR SPLICE OF COAXIAL CABLE & (2) NO. 18 WIRES
*ULTRASONIC TRANSDUCER "HEAD"
TO SUIT
18 in. MIN. (AT HIGH FLOW)
ANGLE TO SUIT
3 ft MAX. (AT ZERO FLOW)

[NOTE: Bottom surface of transducer "head" MUST be parallel to liquid surface.

Source: Tri-Aid Sciences, Inc., Rochester, New York

Figure 6. The Tri-Aid Sciences ultrasonic flowmeter has been designed for use with open channel flumes or weirs.

FOR: RECTANGULAR WEIRS * CIPPOLETTI WEIRS * TRAPEZOIDAL WEIRS * "V NOTCH" WEIRS
PARABOLIC FLUMES * PARSHALL FLUMES * LEOPOLD-LAGCO FLUMES



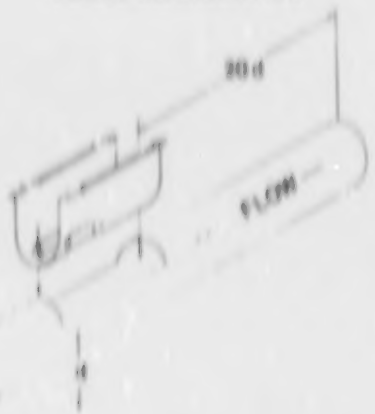
Source: Environmental Measurement Systems, Seattle, Washington

Figure 7. Environmental Measurement Systems ultrasonic measuring devices have been designed for use with flumes of all types and weirs.

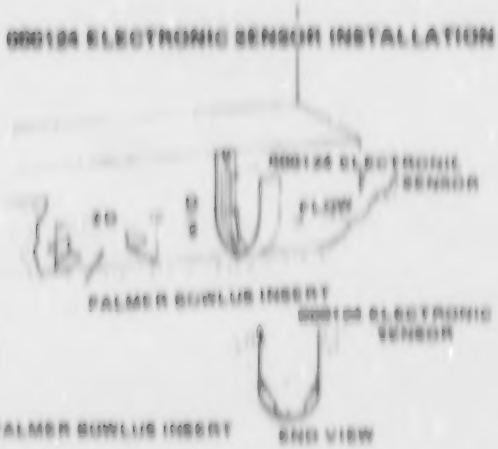
Source: UES Universal Engineered Systems, Inc., Pleasanton, California

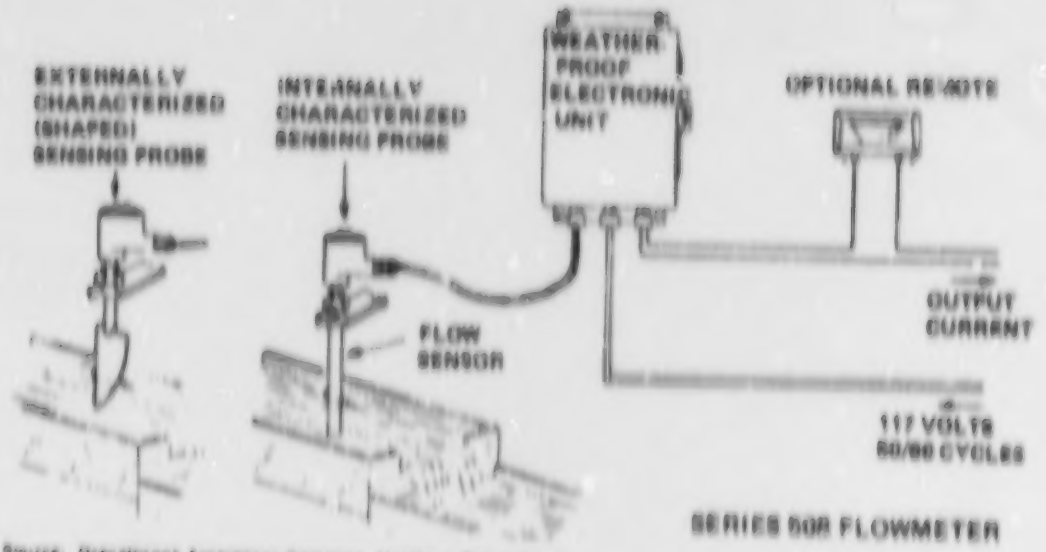
Figure 8. The UES measuring flumes can be installed in manhole locations or cut into a sewer line. A sensor element embedded in the flume measures liquid levels.

FLUME INSTALLATION



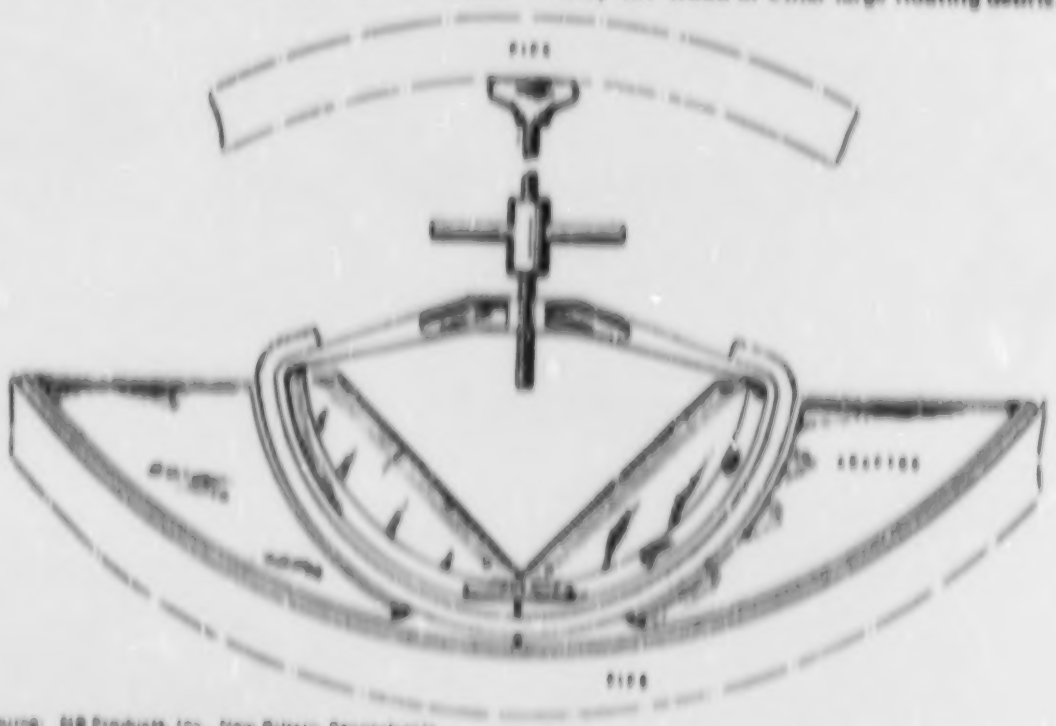
000124 ELECTRONIC SENSOR INSTALLATION





Source: Drexelbrook Engineering Company, Horsham, Pennsylvania

Figure 9. The Drexelbrook flow-measuring systems utilize characterized probes that can be designed to tilt out of the stream if they hit wood or other large floating debris.



Source: NB Products, Inc., New Britain, Pennsylvania

Figure 10. The NB Products V-notch weir can be provided with adaptors so that it can be fitted to a wide variety of pipes.

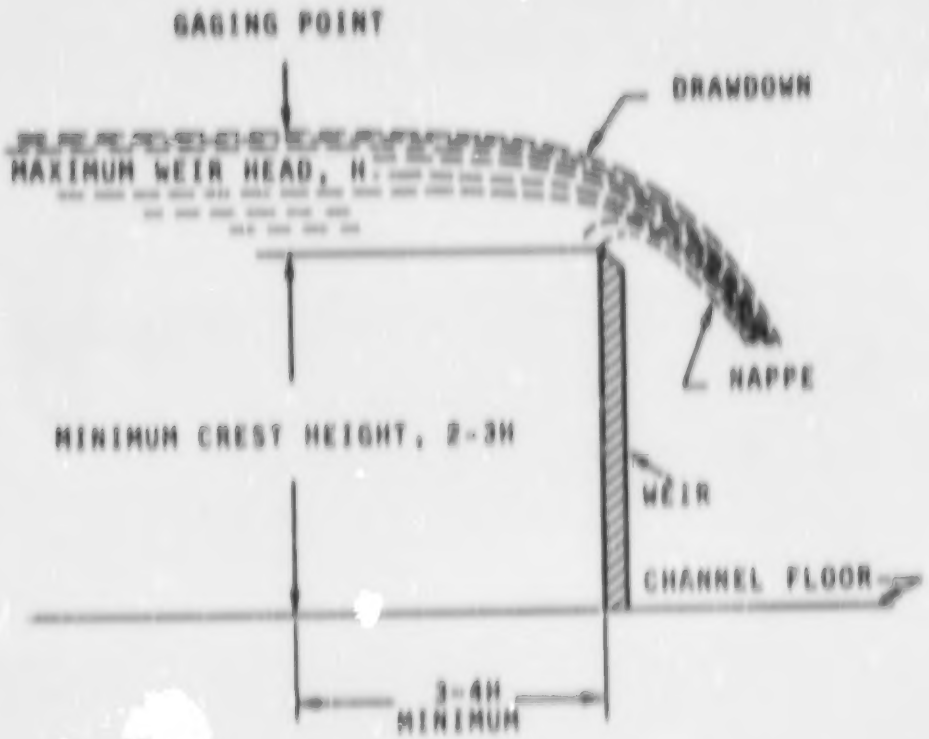


Figure 11. A weir, to function as a precision measuring device, should meet these minimum standard dimensions.

SECTION III

SEWER CLEANING TECHNIQUES AND EQUIPMENT

Before infiltration, inflow, or flow in the sewers can be measured, sewers should be cleaned. With clean sewers, flow readings will be more accurate, inspection by closed-circuit television or other means will be more meaningful, areas subject to infiltration and inflow can be detected with greater accuracy, and the full capacity of the sewer restored. Cleaning makes it possible to detect poor house laterals, joints that have become offset, and breaks in the sewer caused by poor construction or other reasons. Sewers must also be cleaned prior to grouting or lining.

Classifications of Cleaning Methods

Sewer cleaning equipment, for convenience, can be grouped into six general categories:

1. Bucket-type machines.
2. Rodding equipment, both rotating steel and jointed wood rods.
3. High-velocity water jetting.
4. Hydraulically propelled cleaners, including sewer balls and hinged-disc types.
5. Plain flushing.
6. Chemicals.

The sixth category, chemicals, is not really a cleaning method, but a way to inhibit the intrusion of roots into sewers. The persistent entry of roots into the sewer system, even through pipe joints that are well prepared and do not leak, is undoubtedly one of the most troublesome elements in sewer maintenance.

Bucket Cleaning Machines

Bucket machines are strong, positive cleaning units. They can open heavily blocked sewers even though clogged with large masses of roots, sand, or clay. When a crew completes its cleaning work using this type of machine, the sewer should be in good flowing condition, unless it contains broken and damaged sections. Figure 12 shows a typical unit.

One preliminary detail needs attention — crew members must find a way to pass the cable through the length of sewer to be cleaned. One method is to float a light rope through the pipe, assuming that the wastewater flow is large enough to carry it. Another, more positive method is to push the cable through, using lengths of sewer-cleaning rods.

A bucket cleaner consists essentially of two powered winches, each equipped with sufficient steel cable to reach between the two manholes, generally not over 750 ft (229 m). The cleaning crew will center one winch over the influent and the other over the effluent manhole connecting the line being cleaned.

A specially designed bucket serves as the connecting link between the two cables permitting the winches to pull the bucket in either direction. The bucket is designed so that one end opens and closes. One of the winches can then pull the bucket into the sewer, with the bucket end open, so that it can be filled with debris to be removed. When the bucket is full, the other winch pulls it out, closing the bucket end through a mechanical linkage.

Most models of these cleaners can draw the bucket completely out of the manhole and, by use of a small swinging boom or conveyor chute, discharge the debris into a dump truck.

After the operators have removed the bulk of the debris from the sewer line, they can replace the bucket with a "porcupine." This is a drum-like cleaning tool with stiff wire cables protruding outward from the cylindrical side. By drawing it back and forth in the sewer, the operator can remove hair, roots, and grease deposits that the bucket cannot dislodge.

For a final, wiped-clean finish, the operator then can replace the porcupine with a rubber "squeegee." Crew members frequently fabricate these from old belting, roughly 0.5 in. (1.3 cm) thick, and cut to fit snugly inside the pipe to be cleaned. However, the manufacturers of the cleaning equipment can supply them if desired.

After the squeegee passes through the pipe, the sewer should be close to its original, free-flowing condition if it has no outright breaks or other flaws.

Principal Suppliers of Bucket-Type Cleaners

W. S. Darley & Company, 2600 Anson Drive, Melrose Park, Illinois 60160. Can supply bucket-type cleaners mounted on three-wheeled trailers, powered by either a 16-horsepower or a 25-horsepower gasoline motor. Two such units are required. The supplier states that the machines utilize power trains from the engine shaft to the cable drum incorporating a torque limiter that can transmit the full power of the engine to the transmission without slippage or overload failures. The transmission has four forward speeds and one reverse. The main drum can hold 1,000 ft (305 m) of 0.5 in. (1.3 cm) steel cable. An auxiliary drum is provided with each pair of machines. Both buckets and porcupines range from 6 to 22 in. (15 to 56 cm) in diameter.

Current prices are $1,800.00 per machine for the 16-horsepower unit and $2,045.00 for the 25-horsepower. As noted, two are required.

Rockwell International, Municipal and Utility Division, P.O. Box 47767, Dallas, Texas 75247. Manufactures three basic models of bucket machines: (1) the Pick-Up Loder which is designed to dump directly onto the street or into containers for transfer to the disposal area; (2) the Truck Loder which carries the bucket up a conveyor to dump into a truck; and (3) the regular Pull In Machine. Sizes range from 9 horsepower to 100 horsepower for cleaning a wide variety of sewer pipes. The manufacturer makes special sizes of buckets for large pipes and for use in various manhole sizes.

W. H. Stewart, Inc., P.O. Box 797, Syracuse, New York 13201. Manufactures bucket machines in six sizes with engines varying from 10 to 65 horsepower. The units have three-speed transmissions and are capable of dumping 48 in. (122 cm) buckets. They are designed to load into either containers or trucks.

Rotating Rod Sewer Cleaners

Rotating-rod sewer cleaning equipment such as shown in Figures 13 and 14 also has proved practical and useful in returning clogged sewers to service. These consist of high-strength flexible rods of an oil-tempered spring steel, supplied in sections so that if a rod breaks the broken section can be removed and the machine returned to service. The rods generally are 3/8 in. (1 cm) in diameter.

A powered sewer-rodding machine can push the rods through a sewer for a distance as great as 800 ft (244 m). It can also maneuver around curved sections. In one unusual cleaning incident, the rods successfully removed a latex spill that produced a plug 250 ft (76 m) long in a 10 in. (25 cm), two-barrel sewer siphon.

The rods can be supplied with a variety of tools to expedite the cleaning operation. To open a line that is completely plugged, the operator can place a small spear or round-wire "corkscrew" device on the end of the rod. The cleaning unit will rotate the rod into the plugged sewer to make an opening large enough to permit the wastewater to start flowing.

The operator can then replace the corkscrew with an "auger" or a heavy-duty corkscrew, as conditions dictate. These are spiral-shaped cutting devices with diameters equal to or slightly smaller than that of the pipe to be cleaned. The cleaning machine rotates the rods with the cutters, forcing them into the sewer to capture as much of the clogging material on the spiral-shaped cutting device as it can, and then removes the rod and the material.

The rodding machine should be positioned from 8 to 10 ft (2.4 to 3.0 m) downstream from the manhole connecting with the sewer to be cleaned. This assumes that the operators will insert the rods upstream so that they can withdraw them, and the debris, downstream. At this distance from the manhole, the rod sections can be fed into the rod guide channel and then into the sewer with as few sharp bends as possible.

The operator always must adjust the footage indicator on the machine to zero before inserting the rods into the sewer. This identifies how far the cleaning tool is in the sewer at all times. All models automatically add and subtract footage.

When inserting the rod and cleaning tool the operator always should allow the cleaner to build up rotating speed to a maximum before moving the rods forward. If the line is fairly clean, the rotating rod can be moved quickly and easily. The safety-overload device releases or indicates pressure when cleaning becomes difficult. Operations can continue if the pressure is minor, but the forward speed should be reduced and the rod spin kept at a maximum.

If the rods and the cutter appear to be making no forward progress and the safety overload device shows continued heavy pressure, the cutters probably have encountered a heavy mass of roots or other obstructions. To clear them, the operator should reverse the controls, remove the rods and cutter, clean the cutter of entangling roots, and then run the rod and cutter back to break through the obstruction.

Rods *can* be pulled back without rotating, but in general they should not be. However, the spring-blade cutters can be attached successfully at the upstream manhole and pulled back with the cutter rotating at maximum speed.

On most machines, the operator can exert extra power to break through difficult obstructions by tightening the overload safety device slightly. This may be necessary if the sewer is badly sanded. Power rodders also are available with hydraulic systems, and the hydraulic units themselves may be set so that an overload system is a safe way to operate. It also permits the unit to perform at maximum efficiency.

Many cleaning tools can be used by the powered rodding machines. Among them are:

1. *Root saws.*
2. *Corkscrews with back cutter edges.*
3. *Expandable cutters* fitted with two or three knife-shaped blades that can adjust to the diameter of the sewer being cleaned. These blades can be removed for sharpening.
4. *Sand cups* which are rubber discs designed to stop the flow of wastewater, but to permit passage of a portion through holes in the disc, thereby creating jets which flush the material ahead to the downstream manhole.
5. A *pick-up* tool which is an auger-like unit designed to retrieve broken rods from the sewer line.

Principal Suppliers of Rotating Rod Sewer Cleaners

O'Brien Mfg. Division, Cusco, Inc., 5640 Northwest Highway, Chicago, Illinois 60646. Can supply five different types of sewer rodding machines. Three are trailer-mounted units and two are truck-mounted. The machines are variable in that they can make use of rods with lengths of 36, 39, or 48 in. (91, 99, or 122 cm). The machines can be equipped with engines of varying horsepower.

O.K. Champion Corp., P.O. Box 585, Hammond, Indiana 46320. Can supply six models of truck-mounted, rotating-rod sewer cleaners, powered either by separate engine or truck power take-off. Rod diameters vary from 0.375 to 0.461 in. (1 to 1.2 cm). Current prices range from $5,130.00 to $8,346.00.

The company also can provide four models of trailer-mounted power rodders. Current prices range from $2,561.00 to $3,887.00.

Ridge Tool Company, 400 Clark Street, Elyria, Ohio 44036. Manufactures two models of small rodding machines designed to clean sewers with maximum diameters of 24 in. (61 cm), to a maximum sewer length of 500 ft (152 m). Both are mounted on rubber-tired platforms and are easily moved.

The K-1000 rodder is powered by a five-horsepower gasoline motor and has a gearshift providing three speeds forward and one reverse. Its weight is 229 lbs (104 kg).

The K-3000 is powered by a 1,500-watt electric generator with a 3.8 horsepower gasoline motor. The generator has two extra 115-volt outlets for other electrical tools. Complete shipping weight is 393 lbs (178 kg).

Both also can be adapted to spiral-wound cables for cleaning (see following discussion of spring cable cleaners).

The company can provide a variety of cleaning tools for use with the K-1000 and the K-3000 rodders.

Rockwell International, Municipal and Utilities Division, P.O. Box 4776, Dallas, Texas 75247. Can supply five different sectional rodding machines. All can be truck

mounted. The first, the RHRS, features hydraulic power with infinite variable speeds. The rod-driving unit can be slanted toward the manhole, reducing the angle of entry. The rod-storage reel is in line with the lateral movement of the rods, thereby reducing rod bends and the chance of breakage.

The second, the SSR-2, is trailer mounted and has a counter-balanced, cone-type reel that helps prevent rod-twisting under power.

The third, the SCPS, is an intermediate size, built for those who want a smaller machine at a slightly lower price.

The fourth, the RPRS Pipe ROOter,® has been designed for use in the smaller sewer systems where cleaning is fairly infrequent but the safety and mechanical speed of cleaning are desired. The company offers a wide variety of cleaning tools to be used with the rodding equipment.

The company also provides a small unit mounted on two wheels, the PD50RL, for cleaning smaller lines and presumably service connections. It is powered by a three-horsepower motor.

W. H. Stewart, P.O. Box 767, Syracuse, New York 13201. Produces the two model series powered by engines from 10 to 65 horsepower, all with hydrostatic transmissions. Units are built for trailer or truck mounting and supplied with a wide variety of cleaning tools. All units are capable of variable speed with an in-line feed arrangement. The company produces smaller machines powered by 3.5- and 5-HP engines with three- and five-speed transmissions for smaller sewer districts.

Spring Cable Sewer Cleaners

Another type of sewer cleaner, developed originally to open service lines and clogged plumbing, consists of a double spiral cable, with one spiral inside the other turning in opposite directions thus reducing the possibility of helixing either cable, regardless of which direction it is being turned.

The suppliers can provide a variety of cutters to be attached to the cleaning end of the cable. The other end is connected to a power source, either a gasoline engine or electric.

Principal Suppliers of Spring-Cable Type Cleaners

W. S. Darley & Company, 2000 Ansun Drive, Melrose Park, Illinois 60106. Supplies two models of spring-cable cleaners, the model H314 and the model M169. Both will clean sewers to 12 in. (30 cm) in diameter. The H314 is mounted on a pipe frame with a pair of 8 in. (20 cm) pneumatic tires to aid in moving, and is powered by a 0.25-HP electric motor. The M169 is mounted on a dolly and is powered by a 0.5-HP electric motor. Both are supplied with a limited assortment of cleaning knives.

The current price of the H314 is $496.75 and of the M169, $768.65.

Electric Eel Manufacturing Company, Inc., 901 West Leffel Lane, Springfield, Ohio 45501. Supplies a gasoline-powered cleaner, model 325, able to clean sewers to 14 in. (36 cm) in diameter for a maximum of 500 ft (152 m). The machine can be operated by one man, can develop rotating speeds of from 350 to 1,050 rpm, has a single reverse speed, and is mounted on a wheeled dolly.

The current price of the model 325 is $750.75. A transporting trailer, cable reel 500 ft (152 m) capacity, cable, cleaning tools, and accessories are extra.

Ridge Tool Company, 400 Clark Street, Elyria, Ohio 44036. Manufactures a variety of small cable-type cleaners, electrically or gasoline powered and able to clean lines from 200 to 300 ft (61 to 91 m) long. Also produces the K-1000 and the K-2000 cutters which are adaptable to flexible cables and able to clear lines of 500 ft (152 m).

Jointed Wood Cleaning Rods

The manually operated, jointed, wood cleaning rods have the longest continuous record of service in sewer maintenance of any other tool or equipment. They vary from 3 to 4 ft (0.9 to 1.2 m) in length, and are equipped with metal couplings so that they can be joined and thrust into the sewer for as great a length as the maintenance personnel are physically able to handle. The wood rods are used in storm drains and culverts where heavy

deposition of mud and stones cause steel rods to burrow in. The rods generally need to be lifted to an angle of 90° to be uncoupled, so the possibility of their being uncoupled while in the sewer is not great. An assortment of tools is available to be secured to the lead rod to assist in the cleaning work.

Principal Suppliers of Wood Cleaning Rods

W. S. Darley & Company, 2000 Anson Drive, Melrose Park, Illinois 60160.

W. H. Stewart, Inc., P.O. Box 767, Syracuse, New York 13201.

High-Velocity Sewer Cleaning

High-velocity sewer cleaning using water pressure as the cleaning agent is a relatively recent development that is producing excellent results. Under favorable conditions, it has demonstrated an ability to clean a line faster, and with greater efficiency, than any of the older methods.

It has many advantages. It operates at street level without requiring anyone to climb down the manhole; it requires very little time to set the cleaning machine in place; and an operator can quickly and thoroughly flush out a sewer at least 500 ft (152 m) long, and possibly 1,000 ft (305 m) if the cleaning is not difficult. Figures 15, 16, and 17 show typical units.

Although the system uses water at high pressures, tests have shown that the water does not usually harm the pipe joints. The method should be especially useful in cleaning curvilinear laid lines of plastic or asbestos-cement where the buckets and cutters might harm the pipe walls.

The cleaning unit can carry an independent supply of water, generally 1,000 gal (3,785 l). It will be supplied with a pump with a capacity generally of 60 gpm (227 l/m) delivering water at a pressure of 1,000 psi (70 kgf/cm^2) or more. The cleaner usually is supplied with 500 to 600 ft (152 to 183 m) of 1 in. (2.5 cm) heavy-duty hose.

The hose nozzle provides the cleaning action. The nozzle is equipped with a backspray that forces it and the hose down the sewer to be cleaned. A single hole in the front of the nozzle releases a jet of water that opens a path for the nozzle and hose.

When the operator withdraws the hose, the backspray water jets scour the sewer clean and move the debris to the manhole where the hose and nozzle have been inserted into the sewer. The most satisfactory way of removing the debris is with one of the various suction-type units, making it possible for all the work to be performed from the safety of the street level as shown in Figures 18, 19, and 20.

The hose and nozzle should be inserted at the downstream manhole and moved upstream in the sewer so that the principal cleaning can take place in the downstream direction of the wastewater flow as the nozzle is retracted. If root intrusion is very strong, most of the units can be equipped with a hydraulically operated root cutter and nozzle, as shown in Figure 21.

Principal Suppliers of High-Velocity Jet Cleaners

AAA Pipe Cleaning Corp., 10620 Cedar Avenue, Cleveland, Ohio 44106. The company will rent a variety of sewer-jet cleaning equipment suitable for pipe with diameters from 4 through 74 in. (10 through 188 cm). The company also will rent suction manhole and catchbasin cleaning equipment as well as all other major equipment types on a nationwide basis.

Aquatech, Inc., P.O. Box 1907, Cleveland, Ohio 44106. Manufactures six basic truck-mounted sewer jets: models 600/60, 1060, 1260, 1560, 2060, and 3060. Tank sizes range from 600 to 3,000 gal (2271 to 11,356 l). Nozzle pressures range to 2,100 psi (148 kgf/cm^2), and volume to 71.4 gpm (270 l/m). Also produces tandem-axle trailer units with pressure capabilities to 2,100 psi (148 kgf/cm^2).

Manufacturer states that all units can clean 1,000 ft (305 m) of sewer at a single pass, and can be powered either by truck power-takeoff attachment or by diesel or gasoline engines.

Cleaning nozzle variations include both single and double units for deposits of heavy sand in pipe diameters from 15 to 72 in. (38 to 183 cm). Other variations include the lance/thrust nozzle designed to penetrate heavy obstructions such as hard-packed

grease, and the multi-8 jet vortex nozzle designed to remove excessively large deposits. Accessories include a hydraulic-powered root cutter which the manufacturer states can sever roots 1 in. (2.5 cm) in diameter. As an optional item, the Aquatech cleaners can be supplied with a root-chemical reservoir which can introduce a root-growth inhibitor as a foam into the stubs and inhibit further growth.

The company also produces the VE-1000 Sewer Vac for removing deposits from the manhole as the jet unit is operating.

W. S. Darley & Company, 2000 Anson Drive, Melrose Park, Illinois 60160. Supplies the Darley hydraulic high-pressure sewer cleaner which the company states can be mounted on most makes and models of trucks. The complete unit will carry a water tank holding 1,500 gal. (5,678 l). The pump mounts on the front of the truck. It is a four-stage, series design centrifugal unit able to deliver 60 gpm (227 l/m) at 1,000 psi (70 kgf/cm^2). A hydraulically driven hose reel is mounted at the back. Both the pump and the reel are driven by a truck power-takeoff unit. The reel can carry 500 ft (152 m) of hose. The hose is 1 in. (2.5 cm) in diameter, has a nylon inner tube, braided polyester reinforcing, and polyurethane cover to resist acids, chemicals, and oils.

Central Engineering Company, Inc., 4429 West State Street, Milwaukee, Wisconsin 53208. Produces the Vac-All combination high-pressure sewer cleaner. The unit combines the water-jet sewer cleaning principle with a vacuum system for simultaneous removal of debris and water from the manhole through a 12 in. (30 cm) vacuum intake hose. The water is returned to the sewer through a 6 in. (15 cm) drain while the debris is retained in the body for discharge at a disposal site.

The unit is equipped with a 16 yd^3 (12 m^3) vacuum body and an independent water tank with provision for combining the body and tank capacities. The pump produces a pressure of 2,000 psi (141 kgf/cm^2), is of the three-piston type, and can produce variable pressures. The jet hose is mounted on a power-traversing reel for operation from the left side, the right side, or from the rear of the unit depending on traffic and street width.

The same unit can be used to clean catchbasins, sumps, sludge beds, and similar areas.

Cues, Inc., P.O. Box 5516, Orlando, Florida 32805. Supplies the Cobra high-velocity sewer cleaner which can be mounted on a truck or trailer. These machines are made with a pressure unit able to deliver the nozzle water at 1,000 or 2,500 psi (70 or 176 kgf/cm^2). Tanks can hold either 1,200 or 1,500 gal. (4,542 or 5,678 l). Manufacturer can provide a variety of nozzles for special projects such as cleaning a 4 in. (10 cm) house connection, sand accumulations, and heavy grease incrustations.

Elgin Leach Corp., 222 West Adams Street, Chicago, Illinois 60606. Manufactures the Elgin Jet-Eductor designed primarily to clean catchbasins, sumps, and manholes, operates on a hydraulic venturi principle. As an accessory, the company supplies a sewer-cleaning nozzle with a single forward jet to open the sewer, and a series of backflow jets that wash the debris back to the manhole where the Eductor's Aqua-Vac nozzle can remove it.

Flo-Max, Inc., P.O. Box 125, Boerne, Texas 78006. Supplies the Rooter Sweeper Yin Yang hydraulic cleaners in several models. The standard model is built as a single-axle trailer unit. Skid-mounted models are available for use on flat bed trucks. The unit is powered by a two-cylinder, air-cooled engine. Both hand-start and electric-start models are available. Cleaning pressure is developed by a two plunger, positive displacement pump capable of delivering 22 gpm (83 l/m) at 1,000 psi (70 kgf/cm^2). Holding tank capacities up to 150 gal. (568 l) are available. Hydraulic cleaning nozzles, special purpose nozzles and two-stage chemical application nozzles are available.

FMC Corporation, Agricultural Machinery Division, 5601 East Highland Drive, Jonesboro, Arkansas 72401. Manufactures two basic models of jet-type sewer cleaners. The 300 gal. (1,136 l) trailer model No. 3510, designed for smaller communities, can be purchased skid mounted and also mounted on a 1 ton (909 kg) truck. A second model, No. 6520, can be supplied with

1,250 and 1,750 gal. (4,735 and 6,625 l) tanks and is truck mounted.

The Model 3510 is powered by a Ford 104 four-cylinder engine which powers a three-piston, Bean positive-displacement horizontal pump that delivers 35 gpm (132 l/m) at 1,250 psi (88 kgf/cm^2). The hose reel is hydraulically powered. Two nozzles are supplied with the unit: one with the back jets at a 15° angle for small pipe and tough obstructions and the other at a 35° angle for pipe with less difficult obstructions. This model has a current list price of about $10,900.00.

The truck-mounted Model 6540 is powered by a Ford 300 cubic inch (0.0049 m^3) six-cylinder engine which also powers a Bean positive-displacement three-piston horizontal pump. It delivers 67 gpm (246 l/m) at 1,250 psi (88 kgf/cm^2) standard; 1,600 psi (112 kgf/cm^2) is optional. List price is about $13,500.00. It also has two nozzles identical with those supplied with Model 3510.

Accessories for both models include items such as a root cutter, sand nozzle, penetrator nozzle, lateral line cleaning kit and others.

Hydra-Dy-Namic Cleaners, Inc., Division, T.V. Pipe Inspection Company, Box 125, Boerne, Texas 78006. Supplies various models of the Dy-Namic Hydra Cleaner high-velocity water jetting equipment. The unit may be mounted on a 22,000 lb (9,979 kg) GVW truck having a 94 in. (2.1 m) carrying platform. The unit is also available mounted on a heavy duty, dual axle trailer or skid mounted for use on a flat bed truck.

Water pressure is generated by a triplex plunger, positive displacement pump powered by a six- or eight-cylinder industrial engine. The truck-mounted model is available with a split-shaft power takeoff drive which uses the truck engine to provide power for the unit. The triplex pump is rated at 80 gpm (303 l/m) at 1,230 psi (86 kgf/cm^2).

The cleaner unit is equipped with a tank holding at least 1,120 gal. (4.2 m^3) of water and having six baffled compartments. The tank fill system has an air gap safety valve to prevent cross connections when filling from a hydrant. The hose reel is powered and carries a 1 in. (2.5 cm) plastic hose.

A variety of special nozzles, root cutters, and other accessories are available.

E. E. Myers & Brother Company, Division of McNeil Corporation, 400 Orange Street, Ashland, Ohio 44805. Produces the truck-mounted MHV6 cleaner able to jet-flush sewer runs to 1,000 ft (305 m) in one pass; supplied in six gasoline or diesel engine models with tanks of 1,000, 1,500, or 2,000 gal. (3,785, 5,678, or 7,571 l). Pump pressure is a maximum of 1,650 psi (116 kgf/cm^2). Accessories include sand and grease nozzles, penetrator nozzles, root cutters, and remote controls.

Also produces the trailer-mounted PC20 which can be skid-mounted on a flat bed truck with a minimum bed length of 8 ft (2.4 m). Carries a 300 gal. (1,136 l) heavy steel tank with antisiphoning filler pipe. Equipped with 400 to 500 ft (122 to 152 m) of 0.63 in. (1.6 cm) fabric-reinforced hose that is oil and grease resistant. Pump is rated at 20 gpm (76 l/m) with nozzle discharge pressures of 1,250 psi (88 kgf/cm^2).

The model PC20 is supplied with the same accessories as provided for the MHV6. Other accessories supplied to both models include: footage counter that measures the amount of hose in use at any time; lateral-cleaning kit to clear sewers with diameters of 4 in. (10 cm) or more; sewer sweeper kit with heavy rubber diaphragm; and a vortex nozzle designed to clean sanitary lines with heavy grease and sand accumulations and also useful for cleaning corrugated steel culverts. The Myers trailer model PC20 cleaner has a price range of $7,000.00 to $9,000.00 depending upon accessory variations. The truck-mounted MHV6 sewer cleaners have a pricing variation from $13,000.00 to $20,000.00, less truck. The price variables again are dependent upon accessory selection, engine selection, tank size, etc. Myers presently offers 24 models in the MHV6 series.

Myers-Sherman Company, Streator, Illinois 61314. Supplies the Vactor-Jet Rodder that jet-cleans the sewer and simultaneously provides suction removal of the debris which reportedly lowers back pressure and thereby increases cleaning production. Excess water removed with the debris by suction action passes through a

filter that separates it from the debris, and is returned to the manhole.

The Vac-Jet Rodder carries a 16 yd^3 (12 m^3) box to receive the debris (holds 2,700 gal. [10.2 m^3] of water), and an independent 1,500 gal. (5.69 m^3) tank for jet rodding. An interchange arrangement permits combining both tanks if this is desirable. A variable pressure pump can deliver the jet water at 2,000 psi (141 kgf/cm^2).

The same unit also can be used to clean basins or to flush streets.

O'Brien Manufacturing Division, Conco Incorporated, 5632 Northwest Highway, Chicago, Illinois 60646. Produces four principal models of jet cleaners:

- The *SAJ-1*, truck mounted with remote control and an independent water supply.
- the *SAJ-4*, mounted either on a pick-up truck or four-wheeled trailer, equipped with a 30 gal. (114 l) surge tank and able to develop the same jet pressure as the larger unit.
- the *SAJ-1* and the *SAJ-3*, each mounted on a two-wheeled trailer or skid-mounted. These also carry 30 gal (114 l) surge tanks.

The principal accessory is the O'Brien Root Cutter available for use with any water-jet cleaner. At speeds of 800 r.p.m. the cutter can develop 300 in-lbs (346 cm-kg) of torque and cut through most root stoppages.

Rockwell International, Municipal and Utility Division, P.O. Box 47767, Dallas, Texas 75247. Produces the 701 Hi-Velocity Cleaner and the more complete Hi-Velocity Cleaner and Reclaiming Unit. The first carries 1,200 gal. (4.54 m^3) tank that can be refilled from a nearby fire hydrant. The second carries a 3 in. (8 cm) suction line to remove the debris and water. A cyclone separator removes the solids from the water so that it can be recycled in the jet cleaner.

Sewer-Ball Cleaning

Over the years, the use of a large, rubberized ball to clean sewers that have not become completely blocked has proved its effectiveness. An experienced operator will manipulate the ball to permit wastewater to escape around its lower perimeter at high velocity, thus forcing the obstructing material ahead, into the downstream cleanout manhole. To use the sewer balls, a crew must be equipped with:

1. at least 600 ft (183 m) of 0.5 in. (1.2 cm) synthetic-fiber rope mounted on a spool supported on a rack so that the spool is free to move. For balls over 15 in. (38 cm) in diameter, steel cable is preferred.
2. a rotating swivel with a clevis that serves to attach the rope or cable to the ball.
3. 400 ft (122 m) of 2.5 in. (6.3 cm) hose, and a nonrising stem, air-break gate valve, fitted with connections to attach to a hydrant. The air-break valve prevents cross connections between the potable water in the hydrant and the wastewater.
4. a "hole jack" that has a small, free running wheel to be fitted into the influent manhole, used to control the rope or cable.
5. rubber buckets, appropriate shovels, boots, and safety harnesses for use when crew members may have to enter the manhole.

Before using the sewer-cleaning balls, the crew should plug basement drains with mechanical or pneumatic plugs. This protects adjacent residences and businesses from backflooding.

The hole jack then must be placed in the influent manhole using the screw-type adjustment that anchors the jack rigidly and firmly in place. The wheel of the jack should be above and opposite the sewer opening which serves as the entry point of the ball. This permits the cleaning crew to remove the ball from the sewer and to release the built-up wastewater that has collected in the manhole.

A metal elbow trap must be placed in the downstream manhole. This will confine much of the solid material flushed out by the ball but still will allow passage of the wastewater into the downstream line. Then the rope or cable must be threaded through the jack pulley, secured to the ball, and then the ball must be pushed into the pipe. Any equipment not necessary for cleaning work should then be removed. Finally, water should be introduced into the manhole by the fire hose, raising the level of the liquid in the upstream manhole to a depth of approximately 3 ft (0.9 m).

A few sharp tugs on the rope, permitting some wastewater to escape around the perimeter of the ball, will start the ball moving. Most of the water will escape around the lower surface of the ball since the ball's buoyancy will hold it against the top of the pipe. The static head of wastewater will then force the ball to move rather easily. The operator must keep the rope or cable tight to prevent it from overriding the ball if the ball is not inflated to give a snug fit. As the ball travels, it will break loose small clusters of roots, sand, mud, or any normal buildup of grease. The operator must be alert to keep from being pulled into the mechanism that is releasing the cable in the hole.

The ribbed ball flutters, rather than spins, in the pipe. It will develop about 6 in. (15 cm) of turbulent water on the downstream side, and this water will lift the dirt and debris and float it to the downstream manhole into the elbow trap where it can be shoveled out or removed by suction equipment.

If the ball becomes trapped in the sewer, it can be loosened by a sharp, short withdrawal on the rope or cable. This will draw the ball back, creating a partial vacuum that will level the debris and allow the ball to proceed forward again.

In general, the ball should be inflated with enough air to require the operator to press it slightly when forcing it into the sewer. However, conditions can arise that will require the ball to be underinflated slightly to do a thorough job of cleaning. Daily cleaning runs of 5,000 to 15,000 ft (1,524 to 4,572 m) can be accomplished. The operators must learn through experience how much inflation will be required in the ball. Large cleaning balls are harder to control than small, and more difficult to pass through the manhole from one sewer to the next.

In addition to cleaning sewers, some have found these sewer balls useful in testing newly constructed sewers when means of inspection, such as closed-circuit television and air testing are not available. By passing one of these balls through the new sewer, the inspector can determine whether the contractor built it free of obstructions and obstacles.

Principal Suppliers of Sewer Cleaning Balls

Cherne Industrial, Inc., 5701 South County Road, 18, Edina, Minnesota 55436. Supplies the Cherne Jet cleaning ball in diameters from 6 through 18 in. (15 through 45 cm).

Cues, Inc., P.O. Box 5516, Orlando, Florida 32805. Supplies sewer-cleaning balls in sizes from 6 through 18 in. (15 through 45 cm).

Sidu Manufacturing Company, 3831 Catalina Street, Los Alamitos, California 90720. Manufactures balls 6 to 48 in. (15 to 122 cm).

Hinged-Disc Sewer Cleaners

The hinged-disc cleaner operates in a manner similar to that of the ball. The device is dropped through a manhole and into the outgoing sewer line. The flow is stopped and the accumulated head causes the machine to roll down the pipe. This will continue until debris is encountered. The machine will then stop, causing an accumulation of head behind and upstream, along with a lowering of the water level in the line downstream. A line attached to the unit is then pulled causing the valve to open and discharge the accumulated head into the voided area ahead. The velocity of this moving water is generally three to four times the normal velocity of the sewage and washes the material downstream, where it is removed at the next manhole.

Where larger obstructions are encountered, the machine is pulled back a short distance at the same time causing the above-mentioned flushing action, and when released has a hydraulic ram effect on the obstruction. This operation provides a completely clean pipe of all loose and removable material and also provides a messenger line that can be left in the pipe for the pulling of the TV camera and/or the sensing apparatus.

The force of the hydraulic action increases with the square of the difference of the diameter, while the amount of debris increases only in proportion to the difference in the diameter. As a consequence, the machine's ability and efficiency increases with the size of the pipe. Figures 22 and 23 show typical units.

Principal Suppliers of Hinged-Disc Cleaners

Cues, Inc., P.O. Box 5516, Orlando,

Florida 32805. Supplies the hydraulically propelled Bee-Liner which consists of a piston-like head with a flexible outer rim. The head is hinged so that the upper half can be retracted by the operator manipulating the control cable. Manufacturer states that a small crew can clean 3,000 ft (914 m) of sewer per day. Can fit pipe sizes from 6 to 36 in. (15 to 91 cm).

Fitzgerald Engineering Company, Inc., 3601 Southwest 69th Court, Miami, Florida 33155. Supplies the Sewer Scooter, hydraulically propelled, with shields to fit sewers with diameters varying from 6 to 96 in. (15 to 244 cm).

Plain Flushing

Plain flushing is a simple and rather crude technique that probably can be justified for use in flat areas where solids tend to settle out and become septic and odorous. It requires only a hose connected to a nearby fire hydrant. The hydrant should be equipped with a thoroughly reliable suction breaker to prevent back-siphonage of sewage into the water mains in case of heavy demands on the water system. The hose used for flushing should not be used for the transmission of potable water without being first thoroughly sterilized.

Suction Cleaning of Manholes

As the preceding discussion indicated, many of the cleaning techniques involve flushing the debris to the downstream manhole and then removing it. This can be done manually, using long-handled shovels and scoops with special right-angle shapes. Small cranes with buckets designed to pass through the manhole openings also have proved successful. The most popular equipment today are *pneumatic* and *hydraulic*, and can remove the debris without causing nuisances at the street level.

The *pneumatic* suction units can be mounted either on trucks or trailers. Each will consist of a large body with a tailgate at one end and a high-pressure blower able to develop the required vacuum in the body. A flexible tube, generally about 12 in. (30.5 cm) in diameter, extends sufficiently far so that it can reach into the manhole and draw out the debris by the vacuum action. By this arrangement, the debris does not have to pass through the blower itself. When the body is full, it is transported to the disposal area and emptied by the usual dump-truck mechanisms.

The attractiveness of this method is its adaptability to other maintenance tasks within an urban governing body. The unit can clean catchbasins, pick up street debris gathered and discharged by mechanical sweepers, collect leaves, clean out sumps, pump wet wells, and perform other tasks that otherwise would be arduous and disagreeable.

The *hydraulic suction* cleaning method has a much longer performance record. The cleaning action is created by two pipes secured together. One delivers high-pressure water, at about 100 psi (7 kgf/cm^2) to the cleaning nozzle. An elbow and a venturi direct the water up the cleaning pipe. Through the Bernoulli hydraulic principle, the high water velocity creates a pressure drop in the cleaning nozzle sufficient to remove both the water and the debris in the manhole. The truck carries a water-tight body of 6 to 10 yd^3 (4.6 to 7.6 m^3). The principal limitation on this type of equipment is that the cleaning nozzle is 4 in. (10 cm) in diameter and consequently cannot remove much of the larger debris. Figures 24, 25, and 26 illustrate the range of equipment available.

Principal Suppliers of Suction Manhole-Cleaning Units

Aquatech, Inc., P.O. Box 1907, Cleveland, Ohio 44106. Manufactures the model VE-1000 Sewer Vac designed to remove debris transported to the manhole by the company's sewer-jet equipment. The unit removes both liquids and solids, separates them by a baffle system within the tank, and discharges the water to the sewer system, retaining the solids. The 1,000 gal (3,785 l) holding tank is expected to serve for six to eight hours of hydraulic flushing time. The unit is equipped with a 3 in. (8 cm) self-priming, nonclogging centrifugal suction pump which can handle solids up to 2.8 in. (7.3 cm) in diameter with the impeller coming into direct contact with the solids being removed. The power supply is a 13-horsepower, air-cooled engine with an

electric starter. The unit is usually trailer mounted but can be placed on a truck chassis.

Central Engineering Company, 4429 West Street, Milwaukee, Wisconsin 53208. Produces the Vac-All Street and Catchbasin Cleaner designed to clean manholes, catchbasins, lift-station sumps, sewage plant digesters, grit chambers, sludge beds, and drying beds. Three models are available with 10, 13, and 16 yd^3 (7.7, 10, and 12.2 m^3) capacity. A high vacuum is developed in the body by means of a blower driven by a gasoline or diesel engine. Muck, water, and objects up to 12 in. (30.5 cm) diameter, are sucked up by a 12 in. (30.5 cm) diameter intake hose supported by a hydraulic power boom and push button control. Water is separated from the muck and returned to the manhole through a 6 in. (15 cm) diameter drain hose. The solid material is transported to the disposal site and dumped by means of a hydraulic hoist. The Vac-All also cleans sewers through high-velocity water jets with simultaneous pickup of material from the manhole.

Cues, Inc., 3501 Vineland Road, Orlando, Florida 32805. Manufactures the Muck-Suck debris-removal trailer. The trailer carries a 1,000 gal. (3,785 l) water-tight box which the manufacturer states can receive 4 yd^3 (3 m^3) of debris solids. The trailer is self-dumping.

Elgin Leach Corp., 222 West Adams Street, Chicago, Illinois 60602. Manufactures the Elgin Jet-Eductor which cleans by the hydraulic venturi action. It carries a water-tight box of 6 to 10 yd^3 (4.6 to 7.6 m^3) on a suitable dump truck. It is supplied with an agitator hose which assists in keeping the debris in suspension so that it can be removed. The manufacturer states that the Eductor nozzle can operate at depths of 20 ft (6 m) and that the cleaning action generates a very low noise level. The manufacturer also states that the Eductor can remove water and debris from a manhole at the rate of 345 gpm (1,306 l/m).

By changing the Eductor nozzle, the machine also can be used for high-velocity sewer cleaning.

Industrial and Municipal Engineering, (I.M.E.), P.O. Box 61, U.S. Route 34, East Galva, Illinois 61434. Manufactures vacuum inductors with solids handling capabilities. Vacuum pumps are used with up to 800 cfm (22.7 m^3/min) to 29 in. (73.7 cm) of vacuum. Hydraulic hoists lift the 1,100 to 4,400 gal. (4,160 to 16,650 l) tanks enabling them to dump the solids. The units can be used for sludge hauling, disposal, and spreading.

Naylor Industries, P.O. Box 6507, Pasadena, Texas 77506. Manufactures the ST-1000 Vert-Kleen unit that eliminates manual removal of solids from manholes. A 3 in. (7.5 cm) solids handling pump capable of handling 2.8 in. (7.3 cm) solids is used on the unit. The unit is used in conjunction with the high-velocity sewer cleaners presently on the market. The 1,000 gal. (3,785 l) capacity tank can also be used to haul sludge.

Rockwell International, Municipal and Utilities Division, P.O. Box 4776, Dallas, Texas 75247. Produces a small vacuum-type manhole cleaner for use with the high-velocity cleaning machines.

Super Products, P.O. Box 27225, 8532 West National Avenue, Milwaukee, Wisconsin 53227. Manufactures Supersucker Vacuum street and sewer cleaner. The unit has a liquid volume of 14 yd^3 (10.7 m^3) and uses suction hose diameters of 8, 10, or 12 in. (20.3, 25.4, or 30.5 cm) with a maximum vacuum of 200 in. (5.1 m) of water.

Chemical Root Control

The intrusion of roots into sewers is probably the most destructive single element that faces those maintaining a wastewater collection system.

Over the years, many have attempted to inhibit the growth of roots in sewers by various chemicals, chiefly with copper sulfate placed in the manhole invert, and occasionally by flushing the chemical down the service line through the toilet bowl. However, this has never proved popular because of the belief that copper sulfate will damage the treatment processes, especially those that depend upon biological action. Also, the chemical will not inhibit the growth of roots that do not come in contact with the flowing waste water. Roots generally enter sanitary sewer pipe joints from the top portion and grow down until the tips reach the wastewater where they normally die from lack of oxygen in the

water. However, they continue to grow above the flow, in the sewer atmosphere which is usually saturated with water and nutrient vapor. These conditions enhance root growth and may ultimately block the sewer.

However, research at the University of California, Davis and full-scale testing at the Sacramento County (California) Utilities Division of the Public Works Department have shown the value of using a soil fumigant type of weed killer to inhibit the growth of the roots as they enter the sewer. The fumigant consists of 24.5 percent anhydrous metham (sodium methyldithiocarbonate), 1.77 percent dichlobenil — 2,6 dichlorobenzonitrile, and balance of inert ingredients containing grease emulsifiers, nonionic surfactants, and foaming agents.[5]

With the application methods developed, roots will absorb the killing agent and inhibitor. Even more important, inorganic colloids and soil in the sewer joints and breaks in the pipe will absorb the inhibitor allowing it to be effective for long periods, for as much as three or four years in open joints.

This inhibitor may be applied by the "soak" method, by plugging the lower end of the line to be treated, filling it with solution at 1 percent for an hour or longer, and then allowing the solution to flow downstream to the next pipe to be treated.

A second, more recently developed and apparently superior method is to introduce the fumigant into the sewer as a foam. This requires plugging the sewer at the upstream manhole using a plug that can receive a 1 in. (2.54 cm) pipe connection. The plug must be strong enough to resist a back pressure from the wastewater of 30 psi (2 kgf/cm^2). A foam generator is then connected to the plug, and the foam carrying the fumigant is introduced, completely filling the sewer until it appears in the downstream manhole. After the plug is removed, the wastewater slowly moves under the foam and compresses it into the top portion of the sewer but does not immediately remove it. The foam will cling to the top of the sewer for 30 minutes or more, giving the roots ample time to absorb the fumigant.

To reduce the risk of having the foam enter the house connections, the operator can insert the hose at the downstream manhole to the mid-point of the sewer and start the foaming at that point. Then he can pull the hose slowly back to the downstream manhole as foaming continues. This procedure should prevent pressure buildup that would force the foam into the house laterals.

To inhibit root entry into large mains sufficient for personnel to enter, the root inhibitor can be sprayed into the upper portion of the sewer at the point where root entry appears. The line must be thoroughly ventilated for this work, not only for the general safety of personnel, but also to avoid problems from the inhibitor. The supplier states that metham can decompose and release MIT, a gas which is used for alcoholic aversion therapy. Long-term tests of five or more years indicate only a minor regrowth problem. Mutations in the mat structure have also been observed which appear to reduce the number of hair roots which mat and collect grease.

Volumes I and II of this report contain additional information concerning root control practices.

Principal Suppliers of Chemicals for Root Control

Airrigation Engineering Company, Inc., Box H, Carmel Valley, California 93194. Supplies Vaporooter root inhibitor consisting of anyhdrous sodium methyldithiocarbamate, dichlobenil — 2,6 dichlorobenzonitrile, and certain inert ingredients either in the "soak" or the "foam" formulation. Also supplies the Foamaker generator and appropriate application plugs and accessories. The generator will produce and inject 20 gal. (76 l) of fumigant foam from each 1 gal. (3.8 l) of the 9 percent Vaporooter solution. Five gal. (19 l) of water and 1 qt (0.9 l) of foaming fumigant will produce 100 gal. (3,785 l) of foam. A sewer 12 in. (30 cm) in diameter will require 6 gal. (23 l) of foam per foot (30 cm) of length.

Applied Biochemists, Inc., P.O. Box 25, Mequon, Wisconsin 53029. Supplies copper sulfate.

Cities Service Industries, Chemical Division, P.O. Drawer 50360, Atlanta, Georgia 30302. Supplies copper sulfate.

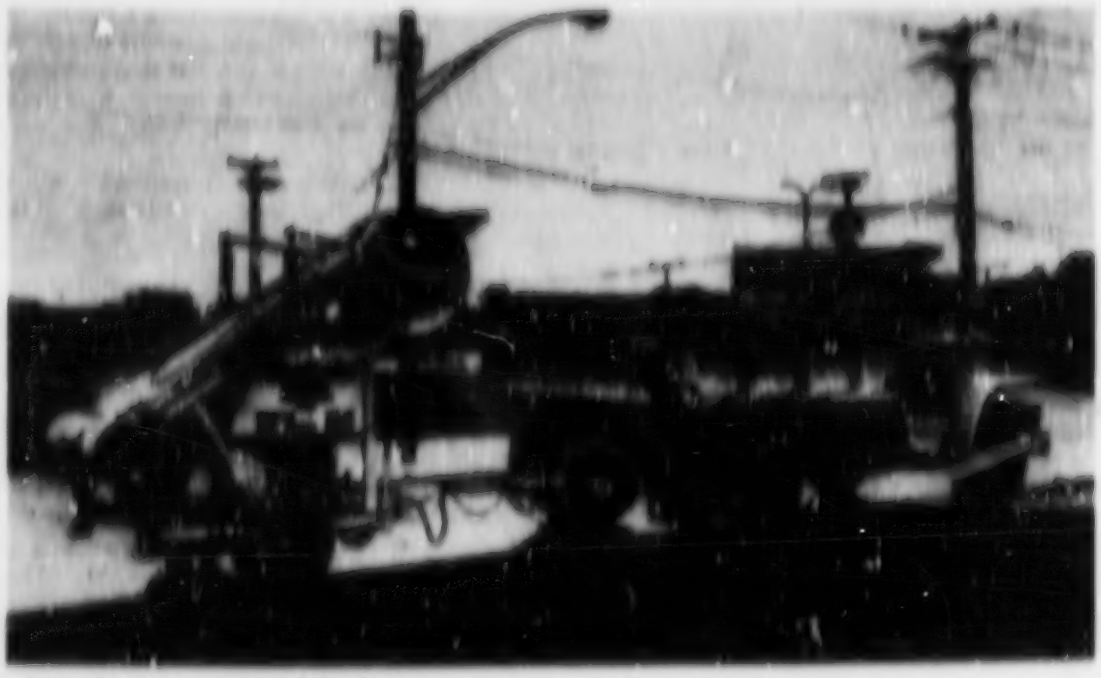
Oxford Chemicals, P.O. Box 80392, Atlanta, Georgia 30341. Distributes Oxford XL 222 delayed action pellets to keep sewer lines open by removing organic matter.

Phelps Dodge Refining Corp., 300 Park Avenue, New York, New York 10022. Supplies copper sulfate.

Reliance Chemicals Corp., P.O. Box 19343, Houston, Texas 77042. Supplies copper sulfate in tablet form as Roostex. Also supplies Bionetics, described as a preserved culture of beneficial micro organisms that can digest sludge, grease, and organic debris.

Rohm and Haas Company, Independence Hall West, Philadelphia, Pennsylvania 19150.

Grout Root Inhibitors. Major suppliers of sewer grout supply formulations with a root inhibitor. See discussions in Section IV.



Source: Rockwell International, Dallas, Texas

Figure 12. A bucket type cleaner with a conveyor loader can be towed easily behind a dump truck.

Source: Aquatech, Inc., Cleveland, Ohio

Figure 13. A trailer mounted rodding machine in operation. Note two spare cutters on manhole lid.

Source: Rockwell International, Dallas, Texas

Figure 14. A trailer mounted rodding unit with the power portion on a small dolly has proven popular among the smaller municipalities.

Source: FMC Corporation, Agricultural Machinery Division, Jonesboro, Arkansas

Figure 15. High-velocity, hydraulic-jet sewer cleaners have demonstrated great usefulness in this phase of sewer maintenance.

Source: Reed-Hycalog International, Dallas, Texas

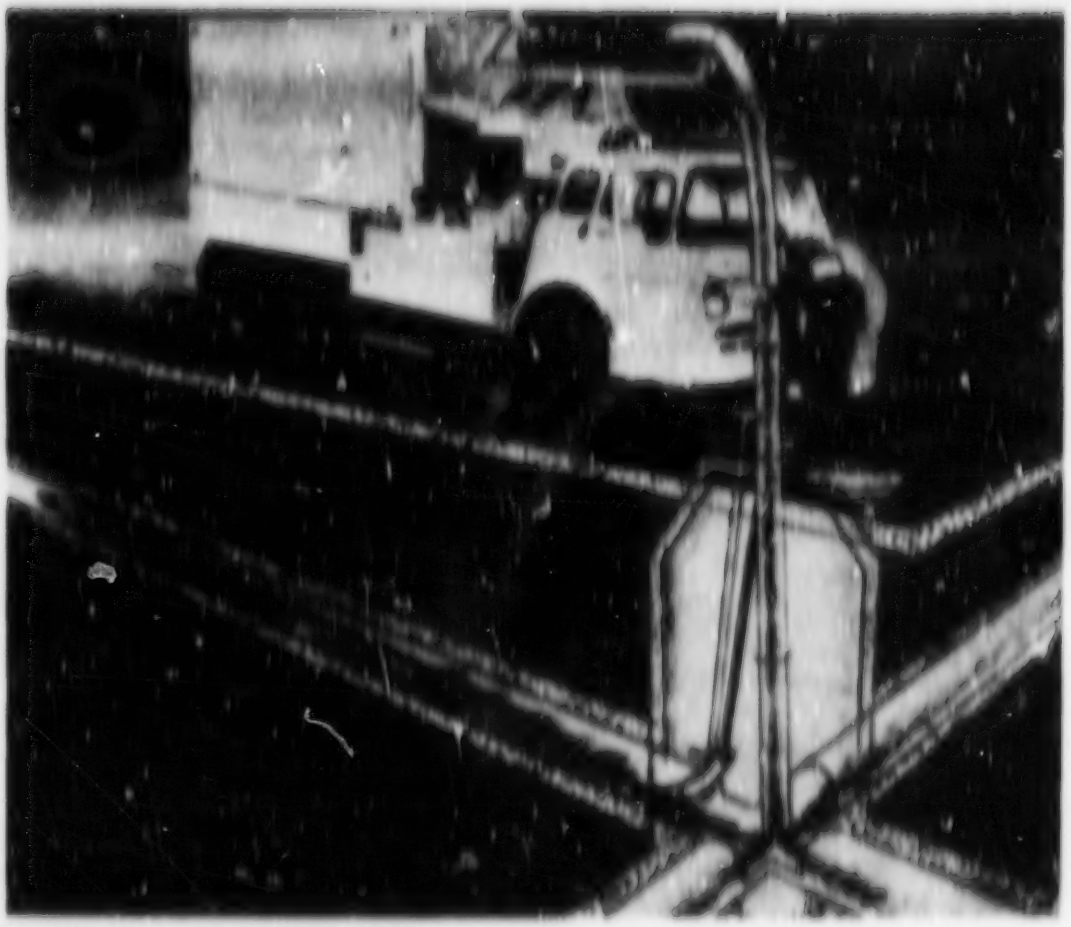
Figure 16. High-velocity sewer cleaners can be provided with a manhole wash-down gun, held by the operator, as well as the usual sewer-cleaning nozzle and the hose roller placed in the manhole.

Figure 17. High-velocity cleaning hose leaves the reel and enters the manhole to perform the jet sewer cleaning.

Source: Rockwell International, Dallas, Texas

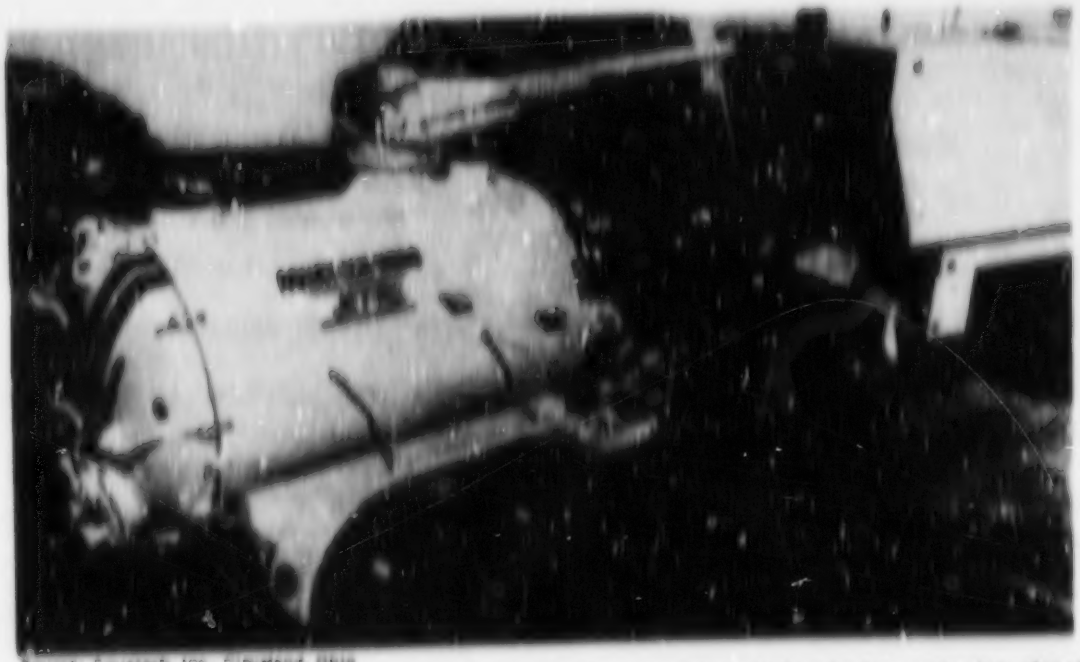
Source: Central Engineering Company, Inc., Milwaukee, Wisconsin

Figure 18. Combination cleaning unit that cleans the sewer by high-velocity water jets and removes the debris by vacuum action.



Source: Myers Sherman Company, Streator, Illinois

Figure 19. Operation of a combination high velocity jet cleaner and vacuum debris removal unit.

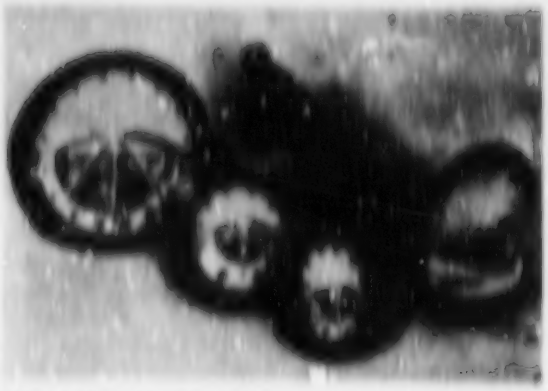


Source: Aquatech, Inc., Cleveland, Ohio

Figure 20. This truck-and-trailer combination brings together high-velocity water-jet cleaning along with vacuum removal of the debris.

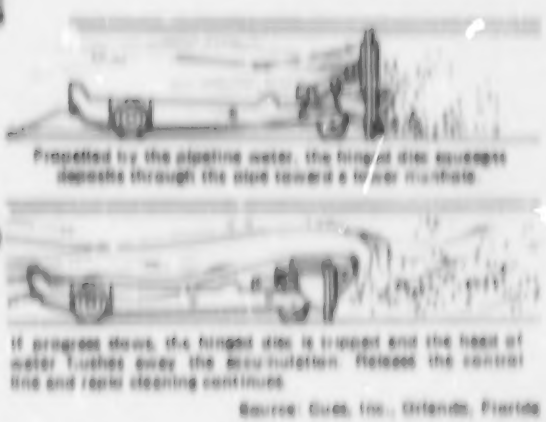
Source: Aquatech, Inc., Cleveland, Ohio

Figure 21. Hydraulically powered cutter secured to the nozzle of a high-velocity cleaner can sever roots that resist the action of the water jets.



Source: Cues, Inc., Orlando, Florida

Figure 22. The hinged-disc cleaner can be provided with a variety of heads to fit various sewer pipe sizes.

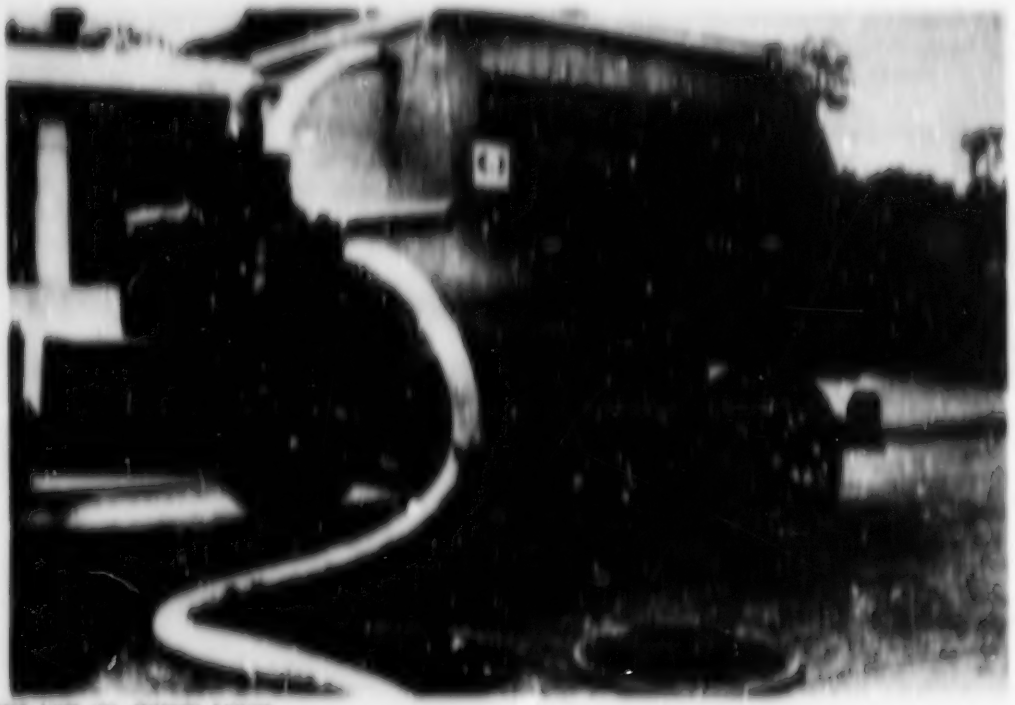

Propelled by the pipeline water, the hinged disc squeegee deposits through the pipe toward a lower manhole
If progress down the hinged disc is trapped and the flood of water flushes over the accumulation. Release the control line and rapid cleaning continues

Source: Cues, Inc., Orlando, Florida

Figure 23. Operation of the hinged-disc cleaner.

Source: Elgin Sweeper Corporation, Chicago, Illinois

Figure 24. The hydraulic manhole and catch-basin cleaner develops its cleaning power through its specially designed nozzle incorporating a 1 in. (2.5 cm) venturi that develops a strong suction, able to draw the debris from the manhole.



Source: Lyon Inc, Orlando, Florida
Figure 25. A hydraulic-type manhole cleaner has a capacity of 1,000 gal. (3,785 l) or a settled debris capacity of four cubic yards.

Source: High Leach Corporation, Chicago, Illinois
Figure 26. A hydraulic-type manhole and catchbasin demonstrates its versatility by also performing as a street flusher.

SECTION IV

SEWER GROUTING

The prevention of infiltration and exfiltration in existing sewers by grouting the leaking joints or small circumferential fractures in the pipes represents a relatively new sewer-rehabilitation technique. The technique is about 20 years old. The results to date have been promising, and the savings in sewer-maintenance costs have often been substantial.

Chemical grouts are most commonly used to seal leaking joints in structurally sound sewer pipes. Radial cracks may also be sealed, but grouting should not be used as a structural repair for broken, cracked, or badly crushed pipe or appurtenant structures. Under normal backfill and groundwater conditions, grouting is generally accomplished with a minimum of difficulty. If there is strong groundwater or earth movement, special techniques may need to be used.

Two patterns of grouting have been used, the first, grouting only joints which appear to have sufficient infiltration to be cost-effective, and the second, to test and seal each joint. Either system may not be totally effective since ungrouted joints may fail at a later date due to high hydrostatic groundwater levels, earth movement, or root intrusion. Thus, for minimum infiltration to be maintained, inspection and grouting should be part of the regular preventative maintenance program.

Types of Grout

Two types of chemical grout are generally used for this work:

1. An acrylamide gel, known either as AM-9 Chemical Grout, Q-Seal, or PWG.
2. A liquid prepolymer that cures to form a flexible, cellular-rubber urethane foam gasket known as 3M Brand Grouting Compound.

The first stabilizes the surrounding soil adjacent to the faulty joint or crack and fills it completely with impermeable grout, including the joint or crack (Fig. 27). The second does not attempt to penetrate the soil, but seals the leaking joint or crack itself.

Acrylamide Gel

The use of the acrylamide gel for sewer rehabilitation is an example of technology transfer. It is an application to sewer technology of chemical soil stabilization that has successfully prevented the flow of groundwater around dams and similar structures, and has prevented the entry of groundwater into tunnels, mines, and other underground structures. It has been used for at least 30 years. With the principles well developed, all that was needed was to adapt them to the special, confined conditions of sewer infiltration and inflow.

The acrylamide gel consists of two organic monomers: acrylamide, and N, N-methylenebisacrylamide. A dilute aqueous solution of the mixture, usually 10 percent by weight, will react to form a gel when catalyzed.

The catalyst commonly used is B-dimethylaminopropionitrile, known more simply as DMAPN. It is a slightly caustic liquid, with no more than 0.5 to 1.5 percent by weight of the total solution needed to activate the reaction.

Beginning in 1975, procedures have been developed to use admixtures with the acrylamide gel to overcome difficulties of application which had previously limited the use of the product under certain situations.

Gel Time

A strong oxidizing salt, ammonium persulfate, initiates the reaction. The gel time begins with its addition. Usually 0.5 to 3.0 percent is needed on a weight basis. The gel time can be varied from 1 to 500 seconds, depending on the amount of DMAPN and ammonium persulfate used. For most sewer grouters using this product, 20 seconds is common. When the gel is used for structural waterproofing, a longer time is needed to permit deeper penetration.

Gel Capabilities

The gel grout can penetrate small leaks and cracks even though water is flowing

through them. Since the gel has a slightly greater specific gravity and viscosity than water, the grout tends to displace rather than mix with the groundwater in the area of the pipe. However, if it is injected into coral, sand, gravel, or coarse rock, the volume of water may be great enough to reduce the effectiveness of the gel. Under conditions like this, one supplier, American Cyanamid, suggests adding a fine, light filler such as diatomaceous earth (Celite 209, a product of Johns Manville Co.), or flyash to the gel to increase strength and viscosity. This technique has been used successfully by several major sewer service companies.

The acrylamide gel performs well when blocking infiltration in leaking sewer joints laid in fine sand below the water table. It has performed successfully in stabilizing and sealing leaking joints in sewers laid in virgin soil.

There appears to be some tendency for the grout to dehydrate where soil conditions are very dry, such as for shallow storm-sewer lines. This possibility can be minimized with the addition of ethylene glycol to the gel. When additives such as diatomaceous earth or calcium chloride are added for strength or to minimize dehydration, the pumping and mixing facilities may need modification as shown in Exhibit 1.

Grouting Procedure Using Acrylic Gel

Before a sewer with infiltration problems can be grouted the pipe must be thoroughly cleaned and freed of obstructions and intruding service connections. This is necessary to permit use of the sealing packer.

The packer consists of a hollow metal cylinder with inflatable rubber sleeves at each end as shown in Figure 27. With the help of a closed-circuit television camera, the operator positions the packer on the joint or crack requiring sealing and inflates the sleeves to create a tight seal with the pipe walls. He then pumps the grouting chemical into the annular space outside the cylinder and between the two inflated sleeves. The pumping pressure forces the grout through the joint or crack and into the soil surrounding the pipe.

After the period of time selected by the operator has passed, the grout solidifies into a gel and produces a seal outside and within the joint or pipe crack. The operator then deflates the sleeves and moves the packer to the next trouble spot in the sewer. Some packing units have a third inflatable section in the center which is used to "push" the liquid grout into the joint. Television is often used to assist in positioning the packer and observing results. A central unit is shown in Figure 28.

Since the acrylamide powder is somewhat toxic, personnel should be equipped with goggles, gloves, and respirators when handling the grout powder.

In all the grouting operations with this product, some gel will remain in the sewer; however, it will be carried away with the wastewater and causes no more problems at the pumps or comminutors than any other solids in the sewage. The packer will dislodge any grout left in the pipe.

Acrylamide gel dries to roughly 80 percent of the liquid volume used. The amount of grout which is used per joint should be carefully controlled. Two schools of thought exist. About 1 gal (3.8 l) per inch (2.5 cm) diameter is used to fill the joint or crack and provide a band of material about the perimeter of the pipe. Others regularly inject three to four times this amount in order to create a large, impenetrable mass to fill void spaces. This practice is sometimes followed on the basis of providing "insurance." Long term tests are needed to determine if the use of the extra grout is cost-effective.

Combination test and grout equipment uses air pressure to detect joints which will not hold pressure for a given period of time. Following grouting, an air test is again performed to test the performance of the grouting procedure.

Root Inhibitor

American Cyanamid blends 200 ppm of dichlobenil with the gel to inhibit the penetration of roots into the sealed joint or crack. The supplier expects the inhibitor to remain effective for a minimum of two years when applied as follows:

1. The sewer line to be repaired is first cleaned, and roots removed to the extent

that a packer unit can be placed and operated satisfactorily within the lines.

2. The joints containing roots are sealed with AM-9 Plus according to manufacturer's directions for AM-9 chemical grout.
3. For those jobs where neither root cutting nor packer placement is feasible, pre-treat the lines with Vaporooter® Plus fumigant according to the manufacturer's directions. After a sufficient period to accomplish root deterioration (1-2 months) follow the steps outlined above in items 1 and 2.

Sealing Small Service Lines

To seal a small service line, generally 4 inches (10 cm) in diameter, the operator would have to utilize a television camera and packer able to function in this restricted space. This equipment can be obtained, but if it is not easily available the line can be plugged at each end and completely filled with the gel, subjecting it to sufficient pressure to permit it to grout all leaks at once.

Urethane Foam Grout

3M® Brand Grouting Compound, the second type available for this work, is a low-viscosity (300-350 centipoise) prepolymer. Solids in the grout constitute 82 to 88 percent of its weight.

When mixed with water, the prepolymer first foams and then forms a flexible cellular rubber. The volumetric increase is about tenfold forcing the grout into the joint or crack that is subject to leakage. After the foaming period ends the grout then solidifies to become the cellular rubber barrier designed to provide sufficient strength and adhesive qualities to prevent the entry or exit of water.

Control of Cure Time

An accelerator whose composition is not identified can be added to hasten the cure time. At a 0.4 percent concentration in the grout, the reduction in cure time is reported by the 3M Company specification sheet for sewer grouting accelerator as follows:

Ambient Temperature of the Grout and Water		Cure Time: Water Only	Cure Time: Water With 0.4 Percent Accelerator
40°F	(4.4°C)	15 min	6.5 min
70°F	(21.1°C)	8.2 min	3.5 min
100°F	(37.7°C)	4.6 min	2.0 min

Maximum linear shrinkage is approximately 18 percent.

Physical Characteristics

The supplier reports that the cured material has a density of 14 lb/ft³ (224 kg/m³), a tensile strength of 80 to 90 psi (5.6 to 6.3 kgf/cm²) and a resilience that will permit elongation of 700 to 800 percent of its original length. It resists most organic solvents, mild acids and alkalis, and retains its characteristics whether the soil is wet or dry. Because of its adhesive characteristics, shrinkage has little effect.

Grouting Procedure Using Urethane Foam

Before a sewer with infiltration problems can be grouted, the pipe must be thoroughly cleaned and freed of obstructions and intruding service connections. This is necessary to permit use of the sealing packer. Joints must be free of protruding roots and only minimum amounts of sand or debris can be in the invert.

The packer that applies the chemical consists of a hollow metal cylinder with three inflatable elements. The outer overall sleeve is coated with a material that will not adhere to the foaming chemical. By use of a closed circuit television camera, the operator positions the packer at the joint or crack to be sealed. The two end elements are inflated to form seals against the inside pipe wall on each side of the point to be sealed.

The urethane prepolymer and water are injected into the annular space created by the two inflated end elements and is allowed to react for the "foam" period, about 35 seconds at 60°F (15.6°C). After the material foams, the overall sleeve of the packer is inflated on the joint for the recommended time to permit the chemical to properly cure. This time will vary depending upon

temperature and the use of accelerator in the water. The operator then deflates the packer elements and moves the packer to the next treatment point. Water is used for testing of pipe joints in the absence of visible infiltration. A drop in water pressure indicates the need for sealing. Joints may be immediately retested following the sealing procedure to insure a proper seal.

In mid-1975 extensive revisions were made to the packer equipment for use with 3M Brand Grouting Compound. Equipment supplied to early users is either being replaced or retrofitted to reduce operational problems. The new models appear to overcome the extensive cleaning problems and premature foaming associated with earlier units.

A desirable feature of the grout system is that the grout is pumped directly from its container. The accelerator is mixed with water which is used both for testing and foaming.

To inhibit root growth, formulations are available with dichlobenil.

Effectiveness

Those who are experienced with 3M Brand Grouting Compound report that it is most successful when used to check infiltration through leaking joints and cracks in concrete pipe and manholes where adhesion is excellent. In some cases it has been found to be less successful on vitrified clay pipe with its smooth, nonporous surface because of reportedly poorer adhesive qualities.

Evidence of the grout's ability to perform as a gasket for long periods rests with an installation placed in a concrete lift station in Minnetonka, Minnesota, in 1970, at a point that was experiencing inflow at the rate of 40,000 gal (151 m^3) per day. The grout successfully stopped the inflow and has shown no signs of distress during the ensuing period.

Care must be used in selecting the volume of grout to be applied to each joint. If too much is used, the excess will form a "skin" hanging from the top of the pipe — or along the invert. One extensive test in Gonzales, Texas, indicated that sewer cleaning would not pull out the grout. However, this possibility is a matter of concern to many until more experience is obtained. Cured foam which is dislodged from the joint could also present a problem at pumps.

Equipment Cleaning

The equipment used to apply the urethane grout requires a detailed cleaning procedure. Acetone is needed to clean and purge the packing unit. For the balance of the system a specially prepared cleaner is required. The compound is flammable, and thus requires appropriate safety practices. It is also caustic, so those using it should be protected with appropriate gloves and safety goggles.

Principal Suppliers of Grouting Material and Equipment

American Cyanamid Company — Industrial Chemicals & Plastics Division, 857 Berdan Avenue, Wayne, New Jersey 07470. Supplies acrylamide gel under the trade name of AM-9, produced to provide controllable gel times. The manufacturer states that it can tolerate some dilution, react in moving water, and produce a continuous, irreversible, impermeable stiff gel in the soil around the sewer joints to control infiltration.

The company also supplies AM-9 Plus chemical grout containing 200 ppm 2, 6-dichlorobensonitrile (dichlobenil) for root control. Dichlobenil is reported to inhibit the penetration of roots into polyacrylamide gel for up to six years when properly applied.

American Cyanimid does not provide grouting equipment. (For a discussion of Vaporomter, see Sec. III, Sewer Cleaning Chemical Root Control).

Cherne Industrial, Inc. — 5701 South County Road 18, Edina, Minnesota, 55436. Supplies the Poly-Meric Sealing System with a wide range of vehicle types, from small trailers to large vans. The sealing material is the 3M Brand Grouting Compound which can be fed through the system without preformulation or mixing.

The sleeve packer has a built-in watertest

feature that can be used to confirm that a leak exists. If the leak is detected, the polymer can be injected into the water in the central cavity of the packer, allowed to react, and then compressed into the leak area. The packer can operate in sewers from 6 through 24 inches (15 through 61 cm) in diameter.

This company also supplies the Cherne Blast-O-Seal system designed to seal leaks in large pipe, from 27 to 120 inches (69 to 305 cm) in diameter. This equipment requires personnel in the sewer to position the packer and apply the poly meric sealing material by a probe applicator. A control cart which also carries the sealing material has been designed for use in the sewer. The same equipment can be used to seal leaks in manholes. The equipment requires appropriate safety precautions governing personnel required to work in sewers (See Section VII, Safety).

Cherne Industrial is also the distributor for the 3M Brand Sewer Grouting Compounds. The sewer grouting chemical is available with or without root inhibitor. The company provides a training program to familiarize the new owner with equipment and procedures to be used.

Cues, Inc. — P.O. Box 5516, Orlando, Florida 32805. Supplies the acrylamide gel grout under the trade name of Q-Seal as well as Cues Seal Root Kill and other chemical grouts for sealing applications. The company has developed over a 10-year period, a variety of equipment units for applying the grout not only to leaking joints and cracks in sewers, but also to leaking manholes, wetwells, and other similar structures. The company provides a training period to familiarize the new owner with the equipment.

Dolfran, Inc. — P.O. Box 13627, Tampa, Florida 33618. Will custom-build equipment for pressure grout and seal a sewer to prevent infiltration and inflow. Supplies grout with a root inhibitor.

Fitzgerald Engineering Company, Inc. — 3601 SW 69 Court, Miami, Florida 33155. Manufactures a complete test and seal unit capable of television inspection and testing of joints and grouting with acrylamide gel. The grouting unit features an inflatable center section to force the grout into the leak and reduce the use of excess gel which would be left inside the pipe. The unit is more costly than two inflatable sealing units; but, the manufacturer claims this is justified because of material savings and fewer resealed joints due to leaking gel.

Halliburton Services — Duncan, Oklahoma 73533. Provides the Halliburton Telespection and Telegrout Systems. The grout system makes use of the acrylamide gel under the company trade identification of PWG. The system uses color-coded mixing tanks and air-driven chemical grout pumps. The group packers can be provided for sewer pipe 6 through 27 inches (15 through 69 cm) in diameter. The system can be purchased, rented, or leased.

Minnesota Mining & Manufacturing Company — (3M), 3M Center, St. Paul, Minnesota 55101. Manufactures a foaming, low-viscosity prepolymer grout, and a sewer-grouting "Accelerator" that shortens and adjusts the foam and cure time. The company also provides a grout cleaner to remove cured and partially cured grout from fittings and hoses.

The company provides sewer sealing chemical with or without a root inhibiting material. Cherne Industrial, Inc., designs and manufactures the equipment to use the 3M Sewer Grouting Chemicals.

Obrien Manufacturing Division, Concrete, Inc. — 5632 Northwest Highway, Chicago, Illinois 60646. Supplies the Search and Seal system which combines television inspection with air testing and grouting with acrylamide gel. The system can be supplied in vans or trailers of various sizes.

Larger Facilities

Rehabilitation of larger facilities such as accessible sewers and manholes can be accomplished by the use of several methods. Figures 29 and 30 show the use of grouting equipment. Most manufacturers of grouting equipment have units for large diameter work.

Other methods which have been used include GUNITE, a sprayed on concrete mixture with a steel reinforcement for sewer pipes and the use of a troweled on water stop in manholes.

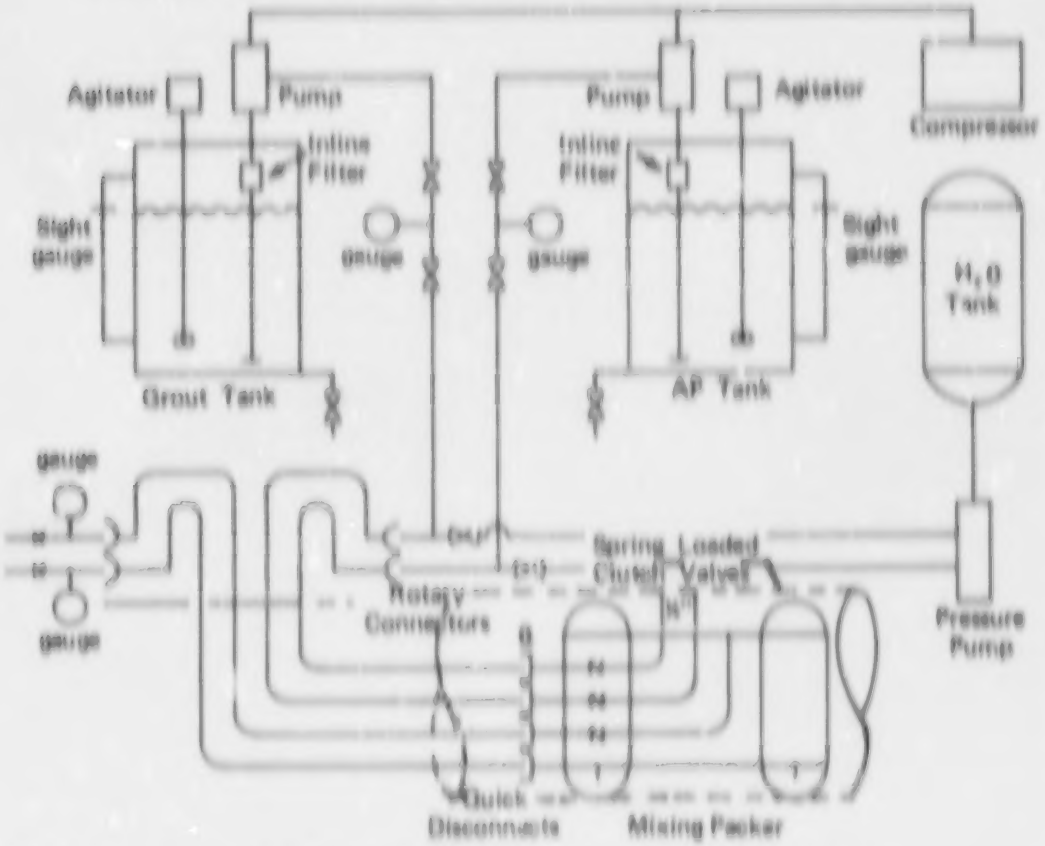
Principal Suppliers

IPA Systems, Inc. – 390 Reed Road, Broomall, Pennsylvania 19008. Manufactures and distributes IPANEX Concrete Admixtures for troweling on to manhole walls to stop passage of water and rehabilitate the structure.

Pressure Concrete Construction Co. – 25th floor, First American Center, Nashville, Tennessee 37238. Provides rehabilitation of manually accessible sewers by the use of "Gunite."

EXHIBIT 1

TYPICAL GROUTING EQUIPMENT FOR INCREASED STRENGTH AM-9



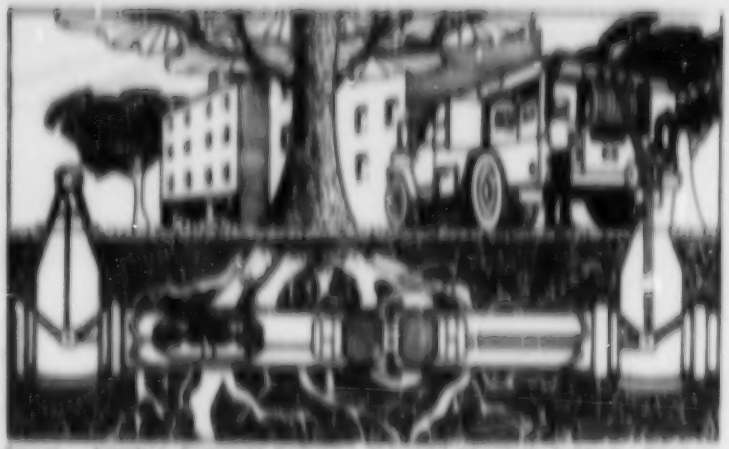
Grout Tank – Water, AM-9 grout, and DMAPN using appropriate formulation.

AP Tank – Water, ammonium persulphate (AP) and Celite 20M diatomaceous earth, in appropriate amounts.

Agitators – are used in each tank to reduce the dissolving time and to keep the solids suspended.

Valves – Quick opening valves are used to maintain equal pressure and *equal volume* of the chemical grout and the ammonium persulphate mixtures in the packer.

Mixing Packer – The mixing packer consists of inflatable neoprene rubber ends on a stainless steel tube with smooth ID tubings leading to the chemical grout and the ammonium persulphate parts. The ports are located one-half inch apart in the center section of the packer.



Source: American Cyanamid Company, Industrial Chemicals & Plastics Division, Wayne, New Jersey

Figure 27. Application of the acrylamide-gel grout. Note the gel that has been pumped to the outside of the joint to stabilize soil and help make it impervious to water entry. The television camera is at left.

Source: Pipetron System, Inc.

Figure 28. Locating a leaking joint by use of the television camera so that the packer can be placed over it.

Source: Minnesota Mining & Manufacturing Company, St. Paul, Minnesota

Figure 29. Joints of a 60-inch (152 cm) storm sewer sealed with urethane foam grout

Two men can effectively seal large diameter pipe joints with the Chance Bisco-O-Seal System. The system is available in pipe diameter sizes from 27 through 120 inches.

The Bisco-O-Seal System is also used to control manhole infiltration. A probe applicator easily injects the sealant into leaking manhole walls.

Source: Chance Industrial, Inc., Edina, Minnesota

Figure 30. Large pipe can be sealed with the urethane grout by using a special grouting ring. The same equipment can be used to seal in manholes.

SECTION V

SEWER INSPECTION AND TESTING

Sewer inspection and testing, as applied to this report, detects weaknesses and faults in pipe and joints that permit the unwanted entry of infiltration and inflow water. Certain of the techniques are also useful for testing the watertight integrity of newly installed sewers as well as insuring the quality of construction. However, since the mileage of existing sewers is far greater than new construction, and since the prevention of unwanted infiltration and inflow insures that the sewerage system will be used effectively, the primary purpose is far more important.

Infiltration/Inflow Defined

Infiltration is the entry of groundwater into the sanitary sewer through imperfections in the pipe wall, pipe joints and manhole walls, and occurs when the groundwater level is above the pipe.

Exfiltration can occur when the groundwater level drops below the pipe, permitting the wastewater to escape through the same pipe and joint imperfections. What can be called *false infiltration* represents condensation on the pipe walls. This may amount to as much as 50 gal/in/mi/d (46.3 l/cm/km/day).

Inflow is the entry of surface water into the sanitary sewer. This may be through illegal connections with the service laterals, introducing flow from: roof downspouts, foundation drains, driveway drains, yard drains and similar sources. It may also come from rodent passageways leading to breaks in the pipe, joint or perforations in manhole covers in areas where the manholes are subject to flooding. (If a manhole is flooded with 6 in. (15 cm) of water over the cover, a single ventilation hole 1 in. (2.5 cm) in diameter can admit over 416 gal (1.5 m^3) of inflow per hour.)

Manhole ventilation holes located in areas subject to these floods should be sealed and maintenance forces should be aware that such manholes will be subject to a much greater risk of dangerous and explosive gases than those with ventilation holes.

Types of Testing and Inspection Methods

Testing of sewers for weaknesses that will permit infiltration and inflow can be grouped into four general categories:

1. Smoke testing.
2. Internal inspection with closed-circuit television inspection of the pipe interior or still color photography.
3. Low-pressure air testing.
4. Infiltration testing.

For internal inspection, most prefer television because of the quick location of problem areas. The television camera also permits a photographic record of those areas where a record is needed.

Smoke Testing

Smoke testing of sewers as shown in Figures 31 and 32 is practical and convincing under proper ground and weather conditions. Many sources of infiltration and inflow exist that are detected easily and positively by smoke.

This method can find leaks and breaks in pipes as shown in Figure 31. It can disclose connections between roof and cellar drains with the sanitary and combined sewers. These connections can impose heavy peak loads on the systems during a storm and can cause flooded basements and similar damage. Smoke testing can identify leaky manholes that can introduce unwanted water, and can locate rodent passages that will do the same.

Types of Smoke

Smoke can be supplied either by "candles" or "bombs" that produce a zinc-chloride mist or by a generator that creates "smoke" composed of DOP (dioctylphthalate) aerosol which consists of particles 0.6 microns in size and thus is able to pass through relatively dense soil successfully. Both types can be supplied in colors varying from white to grey. Suppliers state that the smoke leaves no residue to stain building surfaces or clothing and that it is noncorrosive. Both are nontoxic but can produce a coughing spasm if breathed in large amounts.

To be effective, the candle, bomb, or generator should produce a smoke volume no more than five to six times that of the volume of the sewer section being tested. A "three-minute" bomb should suffice for a sewer run of 300 ft (91 m), and a "five minute" bomb for larger.

Preliminary Details

Before undertaking a smoke test, the sewer authorities should notify both the police and fire departments so that they will be prepared when they receive calls about unexpected smoke emerging from unsuspected locations, especially from buildings. All residents in homes connected with the sewer to be tested should be notified, as well as those connected with adjoining lines in case the smoke works its way into them. Residents should also be encouraged to check that a water seal exists in trapped drains.

Principal Manufacturers of Smoke-Testing Equipment

Air Techniques, Inc. — 1717 Whitehead Rd., Baltimore, Maryland 21207. Can supply a complete smoke-inspection system or separate parts as desired. The system operates using DOP (dioctylphthalate) as the smoke source. Current prices are:

Complete smoke-inspection system, (TDA-5A) smoke generator, manhole cover and blower, electric generator	$1,800
Same as above without electric generator	$1,425
Smoke generator alone	$1,155
DOP solution	$35/gal ($9.04/l)

Company quotes operating cost of $35 for 8 hours; production of 1 million ft³ (28,317 m³) of smoke in 5 minutes with on-off operation; and smoke particle size of 0.6 micron with ability to penetrate 17 ft (5.2 m) of clay.

Clore, Inc. — P.O. Box 5516, Orlando, Florida 32809. Provides smoke-generating devices utilizing the zinc-chloride mist. Can be supplied as 1-minute, 3-minute, or 5-minute smoke bombs, as a smoke grenade, or as a red or orange smoke pot.

Company also manufactures Q-Air smoke blowers to be placed directly on the manhole opening. The blower is powered by a 3½-horsepower gasoline engine and is able to deliver 1,750 cfm (50 m³/min) against a pressure of about 1 in. (2.5 cm) of water. The blower is mounted on a self-sealing fiberglass manhole plate; a flexible canvas duct can be provided for remote operation.

The company also makes electric-powered blowers able to deliver 1,750 cfm (50 m³/min). The power must be supplied by an auxiliary electric generator. Also a small blower powered by a 12-volt battery is available.

The blower can deliver 600 cfm (17 m³/min).

Superior Signal Company, Inc. — West Greystone Road, Spotswood, New Jersey 08884. Produces a variety of smoke-generating products, all based on the use of zinc-chloride mist. Current prices run as follows:

No. 1A smoke candle, 30 seconds	$7.25/doz.
No. 2B smoke candle, 1 minute	$8.80/doz.
No. 3C smoke bomb, 3 minutes	$16.80/doz.
No. 5D smoke bomb, 5 minutes	$35.00/doz.
smoke grenade	$6.30 each
professional smoke grenade	$6.30 each
white smoke pot	$13.55 each
professional white smoke pot	$14.20 each

Internal Inspection

The availability of the closed-circuit television camera designed to pass through a sewer and show the quality of its workmanship and its present condition has done more to improve sewer construction and maintenance and to protect the sewer from casual damage by other contractors and utilities than any other development. Contractors know that the camera can provide evidence of good or bad workmanship. Building contractors become aware that if they harm a sewer, the television camera will detect it and that they will be held responsible. Contractors have become reticent about conducting blasting operations *after* a sewer has been installed. They also pay more attention to sewer line, grade, bedding and other details of workmanship.

When the camera first became available, most sewer authorities preferred retaining the services of specialists to perform the

inspection. But as the equipment became more simplified, and maintenance personnel grew more familiar with it, both sewer authorities and consultants have acquired the television equipment. The sewer authorities now make use of it for more frequent and thorough inspection of the present condition of the sewer. The consultants use it to insure that construction programs under their supervision are completed to specified standards. A remote controlled winch for pulling the camera is a desirable feature which allows the operator greater control and may reduce manpower requirements.

Elements of TV Inspection

A typical closed-circuit television inspection system consists of:

1. A skid-mounted camera able to pass through a pipe 8 in. (20 cm) or more in diameter (cameras are available that will pass through smaller pipe). [See Figure 34]
2. A light source for the camera.
3. Television cable and steel cable on 1,000 ft (305 m) reels with measuring equipment to locate the camera precisely in the sewer.
4. Sheaves or pulleys for the cables and a hand-powered winch at one end to pull the camera through the sewer. The winch can be electrically powered if desired.
5. A control unit with a television monitor and generally a polaroid camera to photograph and record key locations in the sewer. [See Figure 35]
6. An electric generator to provide power and a communication system between the observer and the crew member powering the winch. [See Figure 36.]

The control unit, generator and communications system generally are housed in a closed truck or trailer body. A 16 mm video-tape motion picture camera also can be supplied to make a continuing permanent record of the inspection for future reference.

Principal Manufacturers of Closed-Circuit Television for Sewer Inspection

Chance Industrial, Inc. — 9701 South County Road 18, Edina, Minnesota 55436. Produces a customized inspection system assembled either in a truck body or trailer. The camera was designed with solid-state circuitry contained in a waterproof housing able to resist 400 psi (28 kgf/cm). The camera is mounted on an adjustable skid assembly that will fit sewer pipe with diameters ranging from 6 to 30 in. (15 to 76 cm) if required. Lens adjustments are made externally. Electronic circuitry is designed to eliminate the need for fuses.

The television monitor carries an electronic footage readout that identifies the location of the camera. Photographs of the monitor automatically include the footage figure.

The television cable and reel contain 1,000 ft (305 m) of cable insulated in PVC and protected by a strain-relief feature with a reported strength of over 1 ton (907 kg).

Remote electric power winches, video display units, video tape recording equipment, and both standard and low-light-level television cameras are also available.

Cues, Inc. — P.O. Box 5516, Orlando, Florida 32805. Produces the Q-TV "sewer evaluation unit" which includes inspection of sewer pipe interiors by closed-circuit television. These evaluation units are supplied in van-mounted trucks, walk-in trailers, and exterior-operated trailers.

The equipment is designed to inspect sewers varying from 4 to 60 in. (10 to 152 cm) in diameter. The operator has complete control of the movement of the camera through the line by means of a powered winch. Information pertaining to the location of the camera in the line, the date of the inspection, and the job code, all are electronically displayed on the video monitor so that the information can either be photographed or video-taped for permanent records.

The Cues television-camera line includes the normal Q-TV camera, the Q-TV camera with a low light-sensitivity vidicon tube, and the Q-TV photo camera which allows the operator to take 35-mm pictures in the sewer of the scene that is viewed above ground at the television monitor.

Fitzgerald Engineering Company, Inc. — 3601 SW 69th Court, Miami, Florida 33155. Supplies the Fitz television cameras that will

permit inspection of sewers varying from 6 to 96 in. (15 to 244 cm) in diameter.

Pro-Max, Inc. – Box 125, Boerne, Texas 78006. Supplies the Ishi CC-200 solid state, 2.25 in. (5.7 cm) diameter camera. The camera has a low light sensitivity image tube and internal lighting built into the camera case. Lines as small as 3 in. (8 cm) can be TV inspected. Camera focus can be adjusted externally without disassembly of the camera case.

A telescoping skid for 6 to 15 inches (15 to 38 cm) lines is normally supplied. Telescoping skids for lines up to 48 inches (122 cm) are available.

The system can be van or trailer mounted or operated as a completely portable system by towing the master trailer on the highway. The master trailer wheel width can be reduced from 40 to 29 in. (102 to 74 cm) for reaching manholes in easements and difficult locations. A two-speed, hand-powered winch mounted on a hand cart carries 1,000 ft (305 m) of 0.125 in. (0.32 cm) steel towing cable for pulling the camera through the sewer.

A solid state 9 in. (23 cm) screen monitor is normally supplied. Larger monitors can be provided. Other accessories available include special skids, electric remote footage meters, video recorders, polaroid camera mounts, electric power rewinds, and complete supporting equipment.

Halliburton Services, Duncan, Oklahoma 73533. Supplies a video camera in two models, 70 and 90, which can operate on 10 percent of the light ordinarily needed. Both will serve to inspect all lines of 6 in. (15 cm) or larger. Both the iris and focus can be adjusted externally. The light assembly for model 70 consists of two quartz-iodine lamps requiring approximately 2.25 amps at 28 volts. The lamps have a rated life of 1,000 hours. The model 90 camera uses a light assembly consisting of 30 small incandescent lamps mounted around the periphery of the assembly to provide improved light distribution and reduce the heat transmitted to the camera components. The light requires only 30 volts and can provide sufficient light for the model 70 camera when used in sewers with diameters of 8 to 76 in. (20 to 193 cm) with a 6 in. (15 cm) set available for either camera.

A two-speed winch assembly that draws the camera through the line being inspected contains 1,000 ft (305 m) of 0.125 in. (0.32 cm) steel cable rated at 1 ton (907 kg). The winch, mounted on a 2-wheel, rubber-tired carrier, is designed to straddle the manhole. An electrically powered winch can be provided.

The system-control unit, mounted with other equipment in a closed truck body, is a solid-state device that controls the electric power supplied to the camera lights. It also serves as an electrical protective device for the entire television system. Power requirements are 115 volts AC, 500 watts.

The television monitor is a 14 in. (36 cm) transistorized unit. A three-station, sound-powered phone system provides the communications needed for the inspection work. A polaroid camera with a close-up lens can be mounted to photograph pictures shown on the monitor and provide a permanent record of existing conditions.

Underground Surveys Corporation – P.O. Box 6119, Fresno, California 93727. Produces a combination pipeline inspection camera arrangement that can provide television viewing on a monitor or stereoscopic photography of the pipe interior. Manufacturer states that the entire system weighs less than 500 lbs (227 kg) and can be operated from the back of a pickup truck.

The television camera operates through an armored covered coaxial cable. The camera has a silicon-target vidicon-image pickup tube and produces a system resolution equal to 600 lines. The winch assembly can accommodate 750 ft (229 m) of the armored cable or 900 ft (244 m) of polypropylene rope for a tag line. For a permanent record of the television survey, the operator can select either a video tape recorder or a Polaroid attachment. A footage counter appears on the screen to locate the position of the camera.

The stereoscopic camera can be installed by removing the video unit and placing it in the same housing. The camera is 29-mm and operates through a flash assembly.

Prices for the complete unit, including three days on-site training, start at $4,995.

Photographic Camera Inspection

Inspectors can view the interior of a sewer system by means of photographic equipment rather than television. The equipment is simpler, requires two hand-operated winches, and a suitably waterproofed camera (generally 35-mm). The winches can accommodate 500 to 700 ft (152 to 213 m) of cable. The operator can photograph the pipe at whatever frequency he wishes, generally every 2 to 5 ft (0.6 to 1.5 m). The photographs can be black and white or color. One supplier offers stereoscopic photography which permits a third dimension in the inspection, not possible by television monitoring.

The principal advantage of photographic inspection is its lower cost. The principal disadvantage is the delay in inspection caused by the need to develop the prints and the possibility that pictures were not taken due to malfunction or obstruction of the camera lens.

Principal Suppliers of Photographic Camera Inspection Equipment

Aquarius, Inc. — 10630 Cedar Avenue, Cleveland, Ohio 44106. Produces a 35-mm camera housed in a waterproof case tested to 100 psi (7 kgf/cm^2). The camera is supported by skids that permit inspection of pipe with diameters from 6 through 24 in. (15 through 61 cm). A strobe light, powered by a 6-volt rechargeable battery, provides photographic illumination. The control winch, holding 500 to 700 ft (152 to 213 m) of cable, has a footage counter, picture "take" button, test light and frame counter.

The supplier reports that the average operating cost is 3 to 4 cents/ft (10 to 13 cents/m) of sewer inspected.

Antcor, Inc. — Box 4713, Rochester, New York 14612. Provides a pipe inspection camera adapted from underwater photography use.

Cues, Inc. — P.O. Box 5516, Orlando, Florida 32805. Produces the Q-TV photo camera as an accessory to its television inspection equipment.

Gelco, Photographic Division — Box 1098, Salem, Oregon 97308. Supplies camera equipment for photographic inspection of large sewers, from 24 to 108 in. (61 to 274 cm) in diameter.

Underground Surveys Corporation — P.O. Box 6119, Fresno, California 93727. Supplies 29 mm stereoptic photographic equipment as an accessory to television inspection.

United Survey, Inc. — 25145 Broadway Avenue, Cleveland, Ohio 44146. Supplies photo-inspection equipment consisting of a 16-mm camera mounted on adjustable skids, gyro balanced to minimize camera "roll over". Camera is pulled by a 2-speed winch with 1,000 ft (305 m) of cable. The system is powered by a 12-volt automobile battery and can be mounted in a pickup truck, van or station wagon. Designed to take a continuous reel of color-positive films covering 2,000 ft (610 m) of sewer at 2 ft (0.6 m) intervals.

Low-Pressure Air Testing of Sewers

When the sewer being tested is *above* the groundwater level, low-pressure air testing of a sewer's resistance to infiltration and exfiltration has largely supplanted water testing because of its greater convenience and speed. The use of water can present problems for sewers placed at a relatively steep grade. Also, air pockets in the house laterals and similar locations can weaken the accuracy of the results.

Air testing of new construction should be conducted immediately after backfilling between two adjacent manholes, permitting the line to be tested before backfilling, and allowing the contractor to make repairs immediately.

While a direct relationship between low-pressure air testing and water testing has not been established, experience indicates that a line that will not pass a water test also will fail the air test.

The American Society for Testing and Materials states that this type of testing should be confined to sewers with maximum diameters of 12 in. (30 cm); however, the air-test table lists diameters as large as 42 in. (107 cm). The ASTM recommendation is for clay pipe.

The test procedure is to flush and clean the line being tested since a wetted interior surface yields more consistent results. The

line should then be plugged, including outlets and laterals. A desirable feature for a sewer plug is the ability to place and retrieve the plug without the necessity of a workman entering the manhole. This is desirable both from a safety and time standpoint. For air permeable pipe such as concrete, the line should be soaked for several hours to insure that it is saturated. Standards have not been advanced for air testing of nonpermeable materials such as steel or ductile iron. Allowances of about 25 percent of that allowed for vitrified clay pipe have been advocated. Test procedures are shown in Figures 37 and 38.

Infiltration Testing

If the groundwater level is above the sewer pipe the sewer can be tested by measuring infiltration flow as described in Section II.

Large Pipe Inspection

Pipe large enough for personnel to enter can be inspected visually and joints can be tested individually. A typical joint-testing device isolates the joints, permits the isolated annular space to be filled with air or water, and pressurizes it so that the inspector can measure the rate of loss. Allowable leakage is measured in volume per foot of pipe multiplied by the distance between joints in feet. However, in actual practice the joint is either bottle tight or sufficiently flawed to require repair.

Principal Suppliers of Sewer Plugs

Cherne Industrial, Inc. — 5701 South County Road 18, Edina, Minnesota 55436. Manufactures four models of pipe plugs: the *Sealdbag*; the *Muni-Ball*; the *Test Ball*; and the *Air-Loc Ball*.

The *Sealdbag* is available in various sizes to 53 in. (135 cm) in diameter and is designed to withstand 18 ft (5.5 m) of hydrostatic pressure. It can be inflated or deflated by remote control.

The *Muni-Ball* is available to fit sewers varying from 6 through 24 in. (15 through 61 cm) and can withstand 30 to 40 ft (9 to 12 m) of hydrostatic pressure. It is equipped with a by-pass plug which permits the wastewater to be pumped beyond the isolated section until the testing or repair work is complete, thereby avoiding the possibility of wastewater backing into domestic or commercial drain systems. The plug has been designed so that it can be deflated and removed from the line by personnel working at street level.

The *Test Ball* is available to fit pipe with diameters 1.25 to 12 in. (3.2 to 30 cm). It has been designed primarily for the plumbing industry; however, it has usefulness in many sewer-maintenance tasks.

The Air-Loc Ball is available in sizes 4 through 24 in. (10 through 61 cm) and is used for low-pressure air testing of newly built sewers.

The company also supplies the *Joint Tester* designed to test by low-pressure air the tightness of joints in pipe from 30 to 120 in. (76 to 305 cm) in diameter. The company will fabricate a tester for other diameters on request.

Cues, Inc. — P.O. Box 5516, Orlando, Florida 32805. Cue-Plugs are available to fit pipes with diameters 4 through 36 in. (10 through 91 cm). All can be installed at ground level by use of the Q inserter system. After completion of the test and repair the personnel can deflate and remove the plug by working at ground level. The plugs will withhold pressure head exceeding 40 ft (12 m) for units used in 4 to 18 in. (10 to 46 cm) pipe, and 20 ft (6.1 m) for those used in 21 to 36 in. (53 to 91 cm) pipe.

The plugs have heavy metallic skids that protect the inflatable and replaceable elements from friction. The plugs are equipped with flow-through connectors which permit bypassing wastewater flow if necessary. The plugs can be inflated by a pressurized air tank that can be operated at street level.

Ferreo Joint Sealer Company — 593 Pleasant, Ferndale, Michigan 48220. The UTP (Underground Test Plug) is available for 3, 4, and 6 in. (7.6, 10.2, and 15.2 cm) nominal pipe size sewer pipe. It is designed to withstand 10 ft (3 m) of hydrostatic pressure when installed into the mouth of a smooth bore pipe. The seal is created by compression; mechanical parts are not used.

Source: Superior Signal Company, Inc., Secaucus, New Jersey

Figure 91. Smoke can be directed into the manhole with the use of any blower community provide, to a sewer maintenance organization and the help of a flexible canvas duct and a suitable cover for the manhole. However, the air smoke blower shown here can be placed directly on the manhole opening. As a safety precaution it should be started *before* it is placed on the manhole.

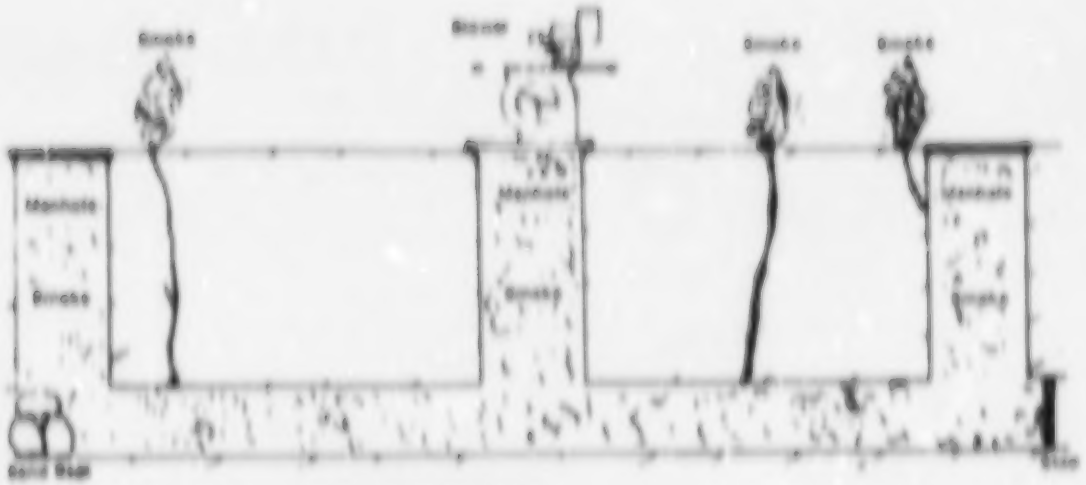
Figure 92. Smoke emerges from a downspout indicating an illegal connection with the sewer

Source: Superior Signal Company, Inc., Secaucus, New Jersey

NB Products — 33 Beulah Road, New Britain, Pennsylvania 18901. Supplies inflatable rubber reinforced pipe stoppers for 6 to 108 in. (30 to 274 cm). All sizes when deflated will fit through the average manhole opening. The plugs are provided with loops in order that they may be secured, inflated and deflated from the surface. Prices vary from $39 to $4,500 depending upon size.

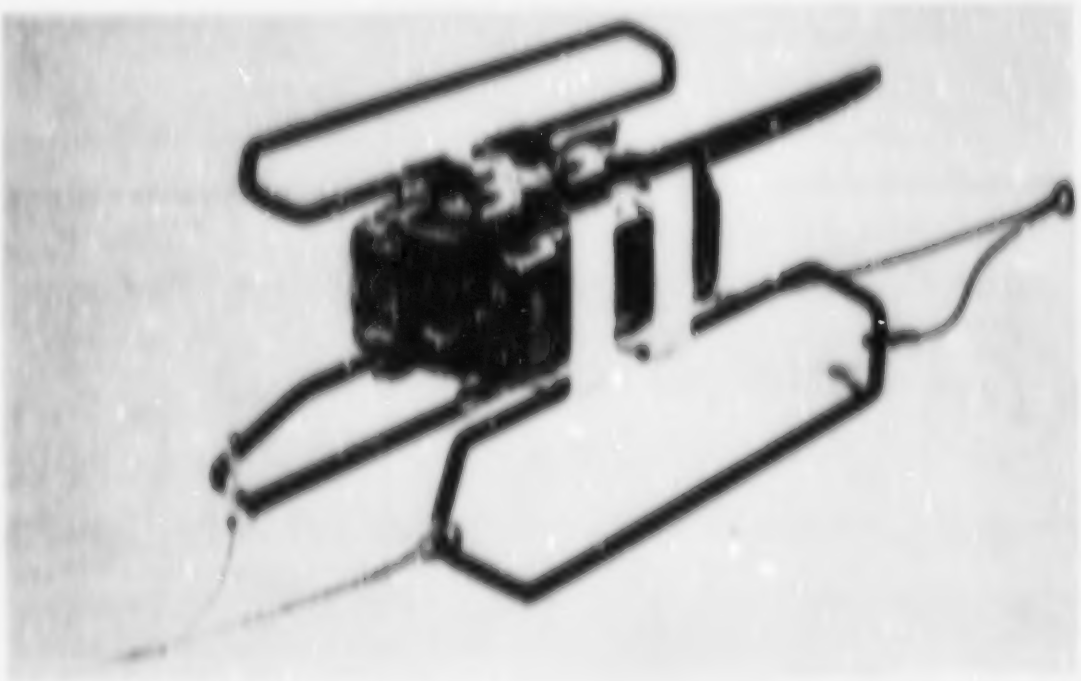
Nortor Industries — P.O. Box 6507, Pasadena, Texas 77506. Manufactures trailer package for I/I survey work, including smoke blowers, inspection equipment, manhole entry kit with blowers, gas detectors, harness, inflatable plugs, compressor and other miscellaneous field equipment.

United Survey, Inc. — Products Division, 24145 Broadway, Cleveland, Ohio 44146. Supplies an Air Test Control Unit with quadrant rollers, air tank, winch and hoses.



Source: Superior Signal Company, Inc., Spotswood, New Jersey

Figure 33. Line being smoke tested is isolated. Smoke identifies the points of infiltration and inflow.

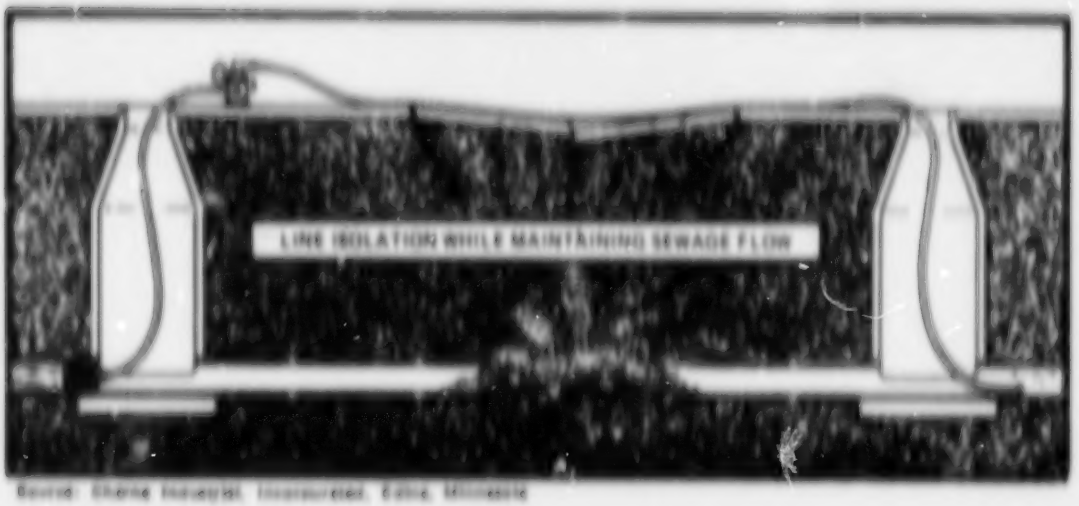


Source: Aquarius, Incorporated, Cleveland, Ohio

Figure 34. Typical television camera for inspection work is waterproof, has its own light source and is mounted on skids for transport through the line.

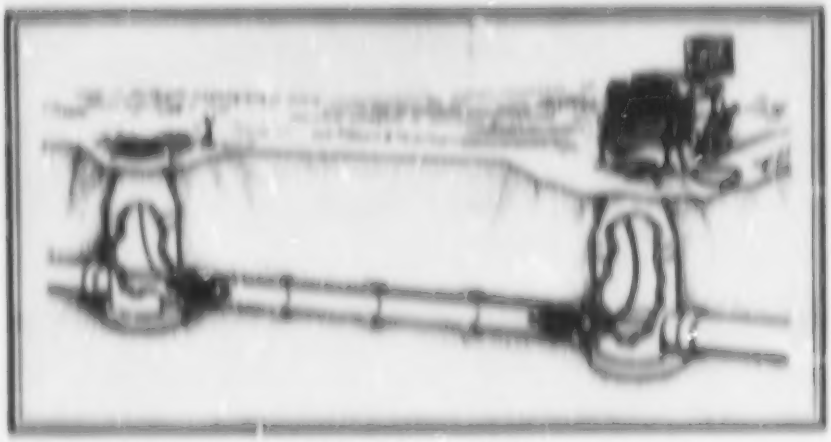
Source: Cues, Incorporated, Orlando, Florida

Figure 35. Control center within trailer shows the television monitor with its remote-reel footage meter located directly above it, and the Polaroid camera mounted on a swinging bracket. A video tape recorder can also be provided.



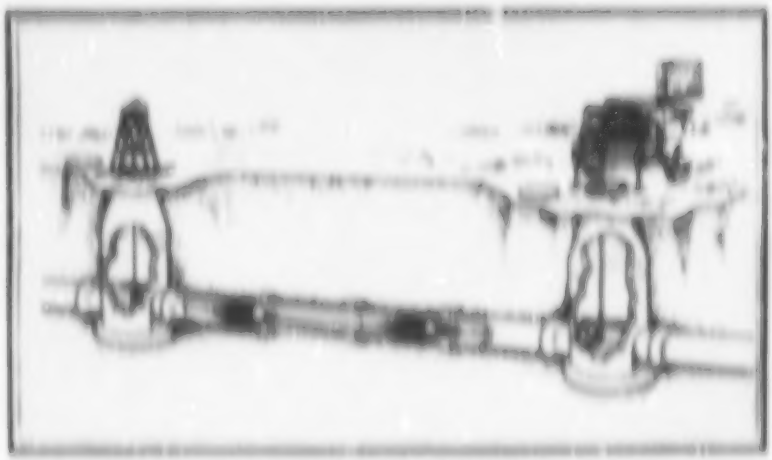
Source: Sherne Industrial, Incorporated, Edina, Minnesota

Figure 36. When the sewer plug is provided with an appropriate connection it can permit repair crews to bypass the damaged portion of the line and maintain service.



Source: Uhlana Industrial, Incorporated, Edina, Minnesota

Figure 87. Testing the integrity of joints in an entire line by low pressure air. Note location of plugs.



Source: Uhlana Industrial, Incorporated, Edina, Minnesota

Figure 88. Testing individual joints by low pressure air. Plugs are connected by cable and pulled to desired section.

SECTION VI

PIPE AND APPURTENANCES

Material for New Construction

In new sewer systems, or in rehabilitation work that requires new conduits, the heavy infiltration characterized by past installations need no longer be a problem. Improved pipe, better jointing materials and techniques, and more meticulous construction procedures if accompanied by rigorous inspection, make it possible to meet stringent, but practical and realistic infiltration rates as currently are being specified.

Manufacturers occasionally mention an ability to meet specifications such as 50 gal/in. dia/mi/day (46.3 l/cm-dia/km/day). However, working specifications for actual construction rarely needs to be that strict, but should be based on a study of the cost of treating this relatively small amount of infiltrated water against the cost of its elimination. Most working specifications currently range between 100 and 250 g.p.d./in-dia/mi/day (93 to 231 l/cm-dia/km/day).

Sewer pipe available to designers today can be grouped into seven general categories: (1) clay pipe; (2) concrete, plain, reinforced and prestressed; (3) corrugated steel; (4) plastic; (5) cast iron and ductile iron; (6) asbestos-cement; and (7) fiber.

Detailed information concerning production standards, testing procedures, design of systems, and construction practices are available from manufacturer associations for the various types of pipes.

Plastic Insertion Pipe for Rehabilitation

The insertion of a continuously welded, flexible plastic pipe into a deteriorating sewer of any type is steadily gaining popularity. The pipe is joined by butt-fusion. Supporters argue that its excellent flow characteristics compensate for the loss of diameter caused by the pipe insertion. The practice avoids the costly and unpopular need to make excavations in well established neighborhoods. Figures 39 and 40 show installation practices.

Trenchless Pipe Laying

Trenchless pipe laying is a new use of butt-fused plastic pipe. A "mole-plow" pulled by a tractor creates the tunnel in the earth into which the plastic pipe is pulled. The system is being tested in Bethany Beach, Delaware. Supporters have not yet presented evidence of how well the method will work in rocky soil, nor in areas with trees and shrubberies with strong root structures. It will probably also have difficulties in areas with other underground utilities as well as sidewalks and concrete curb and gutters.

Principal Suppliers of Plastic Insertion Pipe

Celanese Piping Systems — 4550 Cemetery Road, Hilliard, Ohio 43026. Produces polyethylene (PE) pipe in diameters through 24 in. (61 cm) for relining purposes.

E. I. DuPont de Nemours & Company — Concord Plaza, Wilmington, Delaware 19898. Produces Aldyl "D" PE pipe in diameters from 3 to 48 in. (8 to 122 cm). Company also provides fittings and tools to draw the butt-welded pipe into the sewer. Sewage normally continues to flow through the pipe during the installation. To secure the pipe in place at critical locations such as manhole connections, the manufacturer provides expandable fittings or non-shrink grout. House-connection techniques also have been developed.

Goodall Rubber Company — Whitehead Road, Trenton, New Jersey 08604. Produces PE pipe in diameters 2 to 10 in. (5 to 25 cm). Also provides tapping tool for house connections and joining equipment.

Nipak, Incorporated — 301 South Harwood Street, Dallas, Texas 75221. Produces PE pipe. The company offers the pipe in diameters from 3 to 48 in. (8 to 122 cm) and a variety of wall thicknesses. Nipak provides a complete system for sewer renewal, including the pipe, fittings, tools for insertion of the pipe, and installation assistance.

Phillips Products Company, Inc. — Subsidiary of Phillips Petroleum Company, 2655 Villa Creek Drive, Dallas, Texas 75234. Supplies Driscopipe 7600, PE pipe in diameters varying from 3 to 48 in. (8 to 122 cm). Provides the pipe to a contractor or municipality that will do the actual installation.

Joseph T. Ryerson & Sons, Inc. — P.O. Box 8000-A, Chicago, Illinois 60680. Supplies a high-density PE pipe to serve as a reliner for existing sewer systems. Pipe varies in diameter from 1 to 48 in. (2.5 to 122 cm) but can be fabricated to 80 in. (203 cm). Normal length is 40 ft (12.2 m). Pipe is joined by butt-fusion. Company supplies the pipe for suitably equipped contractor.

M. L. Sheldon Plastics Corporation — Plastics Pipelines Division, 350 Lexington Avenue, New York, New York 10016. Provides high-density PE pressure pipe and fittings in diameters to 48 in. (122 cm). Pipe is butt-fused and pulled through the sewer by an air-actuated vibratory pulling head.

Evanite Development Corporation — 1975 Buxmont Road, Huntington Valley, Pennsylvania 19006. Provides the Badger system of trenchless pipelaying, a British import designed to place an opening at a controlled depth and insert a PVC or other type of plastic pipe in it at the same time. Suppliers state that it can place a pipe as large as 15 in. (38 cm) in diameter to depths of 5.5 ft (1.7 m).

Special Pipe Fittings and Manhole Connections

With the variety of pipe available today, special fittings and connectors have had to be developed. The recognition has grown that the earth is not static but experiences considerable movement throughout the year caused by changes in weather and heavy traffic loads imposed on it. Connectors and fittings have to retain their watertight integrity while adjusting to these changes.

A major point of infiltration in many systems is at the connection of the house lateral to the main. In some instances the lateral has been installed protruding into the main, causing blockage and preventing proper cleaning of mains. Where hand-tapping of the main is permitted, the main will frequently be fractured. In time, the fracture may permit root infiltration and/or the collapse of the main pipe walls. At best, it is a constant maintenance problem.

There are several ways and means of connecting laterals to the main.

1. Concreting the lateral to the main is quite common in many areas. Concrete when dry, shrinks, permitting hairline cracks to occur, thus allowing infiltration.
2. Some saddles or connections react to soil acids and may totally disintegrate in a few years, defeating the purpose of using the saddle or connection.

The following should be considered for lateral connections.

1. No fracturing of main: Mechanically cutting a hole in the main overcomes fracturing and also controls hole size. A hole can be tapped mechanically in about 3 minutes which is a time saver over hand tapping.
2. Preventing lateral protrusion into the main: A properly designed saddle prevents the lateral from entering the main and causing a restricted flow thru the main.
3. Prevent infiltration: Provide proper sealing between main and lateral.
4. Allow for ground movement: In backfilling around the lateral after a tap is made, some settling will take place. Should the connection to the main be too rigid, either the lateral will break or the connection will move permitting infiltration to take place. As the ground is always shifting slightly, it is desirable to have built-in flexibility.
5. Inspection: The ease of making an inspection governs the time spent in backfilling which relates to equipment and labor time.

Figures 41 and 42 show connectors to manholes where shear often causes pipe failure.

Principal Manufacturers of Flexible Connections and Fittings

A-Lok Products Corporation — Box 1476, Trenton, New Jersey 08607.

Manufactures a gasket which is a pipe-to-manhole seal cast integrally into the pipe opening of the manhole base at the time of manufacture. It is a compression joint with no moving parts.

Fernco Joint Sealer Company — 591 Pleasant, Ferndale, Michigan 48220. Manufactures the Donut adapter, an elastomeric material designed to seal by compression for bell and spigot type connections. Most combinations of clay, concrete, cast iron, asbestos cement, ductile iron, fibre, or steel pipe can be connected in size to size or reducing sizes up to 12 in. (30 cm) nominal pipe size. No special tools are necessary for installation.

Also manufactures the Flexible Coupling, an elastomeric sleeve designed for plain end pipe connections. The flexible sleeve is installed over the plain pipe ends and sealed by stainless steel clamping bands on the exterior of the sleeve. The couplings are available in size to size or reducing sizes for material to material or material transitions for most piping materials. Repairs and fitting insertions are made possible by using the coupling.

Sizes are available from 1.5 through 15 in. (3.8 through 38 cm) nominal pipe size.

The Formsert Company — P.O. Box 1193, Manchester, Connecticut 06040. Manufactures Quick Seal flexible connections for precast concrete manholes.

GPK Products, Inc. — P.O. Box 2872, Fargo, North Dakota 58102. Manufactures "Sureflow" PVC fittings in sizes from 4 to 15 in. (10 to 38 cm) primarily for PVC pipe. However, the company also makes some fittings that can be used with clay, cast iron, or other materials. Fittings include a saddle wye; reducing, full, and saddle tees and wyes; bends from 22.5° to 90°; and adapters and couplings that can be used with clay and cast iron pipe.

Interpace Corporation — P.O. Box 1111, Parsippany, New Jersey 07054. Manufactures precast concrete manhole bases and wells with flexible rubber sleeves to receive any type of sewer pipe from 6 through 15 in. (15 through 38 cm) in diameter as well as risers and cones.

Mission Clay Products Corporation — 6533 South Magnolia Avenue, Whittier, California 90608. Manufactures Band Seal couplings and bushings that will permit coupling various types of pipe and allow for changing from one pipe size to another.

National Pollution Control Systems, Inc. — Tenney Avenue, Nashua, New Hampshire, 03060. Manufactures the Kor-N-Seal connector that is not cast-in-place but inserted into a cored hole and sealed by an internal toggle band and external clamping band. The manufacturer states that even a poor and leaking mortared joint can be cored out and replaced with one of these boots. The company asserts that the seal has withstood leakage at 30 psi (2 kgf/cm^2) and can withstand 22° of deflection without distress. The manhole can be cored at the site or at the plant.

Press-Seal Gasket Corporation — P.O. Box 482, Fort Wayne, Indiana, 46808. Manufactures the Press Wedge II system manhole connector which reportedly remains watertight at an external pressure of 15 psi (1 kgf/cm^2) and remains so at a maximum deflection of 15°. Connectors can be supplied for pipes with internal diameters from 4 through 42 in. (10 through 107 cm). The system utilizes an all-rubber gasket anchored permanently in place in the manhole opening for the entry pipe. The gasket has a finned opening on one side. When the sewer pipe has been inserted into the opening, the installer pounds a finned rubber wedge into the gasket opening. The fin permits entry of the wedge but prevents it from pulling out. The installation, reportedly, requires 4 minutes and can be made from either inside or outside the manhole.

Price Brothers Company — P.O. Box 825, Dayton, Ohio 45401. Manufactures manhole connectors.

Resilient Seal Corporation — P.O. Box 374, South Plainfield, New Jersey 07080. Supplies a flexible watertight seal for connecting pipes to manholes. The seal consists of a waffled neoprene rubber gasket embedded into the manhole wall. A stainless steel strap is tightened from inside the manhole. Purchase price is $10 and up, depending upon diameter.

Rimrock Enterprises, Inc. — P.O. Box 14, Colorado City, Colorado 81019. Produces sewer tap saddles of acrylonitrile butadiene styrene (ABS) plastic. Saddles can be bonded to sewer pipe of clay, concrete, plastic, asbestos cement or cast iron, using a quick-setting epoxy. Saddles can connect to laterals of 4 to 6 in. (10 to 15 cm) in diameter and can be secured to sewer pipes with diameters from 8 through 24 in. (20 through 61 cm). Sewer heads are connected to the tap saddle through the use of "Donuts." (see Fernco Joint Sealer Company)

Sealex Manufacturing Corporation — Route 17K, P.O. box 1111, Newburgh, New York 12550. Manufactures the Res-Seal flexible connection for precast concrete manholes.

Thunderline Corporation — 5495 Treadwell, Wayne, Michigan 48148. Manufactures the Link-Seal flexible connector for precast concrete manholes with precast pipe openings. The connector has been designed to fit the curved opening of the manhole without adjustments and be used on pipes from 4 to 84 in. (10 to 213 cm) in diameter or larger. The seal can be installed and tightened from inside the manhole and can be retightened later if a leak occurs through settlement of the manhole or the sewer pipe. The manufacturer states that it remains watertight at 20 psi (1.4 kgf/cm^2).

This same "Link-Seal" can be used also as an annular fitting when a plastic pipe is inserted into the old, deteriorating line. The fitting creates a seal between the O.D. of the plastic insertion pipe and the I.D. of the old sewer line, thus preventing infiltration water from entering the manhole.

Manhole Closure

Openings in manhole lids have been identified in many communities as a point of inflow. Manholes which are inundated can allow significant stormwater flows to enter the system.

The problem has been met in several ways. Some have raised or relocated the manholes and some have welded the lids to the frames and filled in the pick holes or air vents. Rubber plugs have been driven into the openings to effectively seal the lid. A mechanical inner lid has also been developed for those systems where continuous ventilation is desired.

Supplier of Mechanical Manhole Closures

Methods Engineering Corporation — 1102 South Brom Street, Wilmington, Delaware 19805. Manufactures the MEC-1, MEC-2, and the MEC-3 watertight manhole insert. The insert is made of aluminum MEC-1 or plexiglass MEC-2 and fits before the manhole lid. Valves allow air to be drawn into the sewer system. A hydraulic head on the valve forces the valve to seal. The MEC-3 includes frame, cover, and insert. Maximum inflow is 1 gal/day (3.8 l/d).

Nuclear Soil-Density Testing of Sewer-Trench Backfilling for Flexible Sewer Pipe

Careful backfilling of the trench plays an important role in insuring that flexible pipe maintains its integrity since the wall is flexible and requires support. Figure 43 shows the ASTM standard.

Specifications that govern the backfilling of trenches containing plastic sewer pipe require the soil to be compacted to a percent of the optimum proctor density (ASTM Designation: D 2321-74). However, an inspector who tries to determine this density by the conventional sand cone method is handicapped because the test does not provide a rapid determination.

Instead of the sand cone method, nuclear soil-density testing equipment now is available that will provide an immediate soil-density figure. The nuclear method is fast, convenient, completely safe, requires only limited training, and permits making a number of determinations in a short period. The Federal Highway Administration, U.S. Department of Transportation, endorses its use on Federally assisted highway projects, and all states use the method on highway construction almost exclusively. ASTM Designation, D-2922-71 describes the method in detail. The probes also can measure the moisture content in soil and ASTM Designation, D-3017-72 describes this use of the meter. Figures 44 and 45 show the necessary steps.

Types

Current nuclear equipment permits density determination in either of two modes:

1. direct transmission
2. air-gap backscatter

With the first the inspector inserts the nuclear probe into the soil through a punched access hole to depths of from 2 to 8 in (5 to 20 cm). The source transmits gamma photons to a detector which translates them into a density measurement for the soil being tested.

Direct transmission provides the capability of controlling the depth from which measurements are made. Surface effects and chemical composition effects are also minimized. However, since the test is used in place of the sand cone method depth is limited to less than 1 ft (30.5 cm).

With the air-gap backscatter method, both the nuclear source and the detector are placed on the surface of the soil. Gamma photons are directed from the source into the soil and scattered back to the detector. Two readings are required, one with the instrument in contact with the material and the one on the air-gap stand. This reading relates to soil density.

Improvement of Backfilling of All Sewer Trenches

Because of its convenience, nuclear density testing now is gaining acceptance as a means of improving all sewer backfill operations regardless of the type of sewer pipe being used. Briefly, the method is to determine the density of the soil prior to trench excavation and specify that the backfilling, after sewer pipe installation, be placed in 1 ft (0.3 m) lifts and each lift compacted to a density equal to that of the soil density before excavation or 10 percent in excess. The nuclear density meter becomes the sole control device.

Backfilling controlled in this way will prevent settlement of the fill material. It also will insure that the pipe itself is firmly placed, reducing the danger of pipe movement which in turn would cause leaks to occur in the pipe and allow infiltration and inflow to take place. To achieve satisfactory control, full inspection must be given and the depth of each layer of backfill limited to the capability of the compaction equipment, generally 1 ft (30.5 cm).

Principal Suppliers of Nuclear Soil-Density Meters

Campbell Pacific Nuclear Company, 130 Buchanan, Pacheco, California 94553.

Seaman Nuclear Corporation, 1846 W. Wisconsin Avenue, Milwaukee, Wisconsin 53208.

Soiltest, Inc., 2205 Lee Street, Evanston, Illinois 60202.

Troxler Electronic Laboratories, Inc., Research Triangle, P.O. Box 12057, Raleigh, North Carolina 27709.

Determining Deflection, Plastic Sewer Pipe

When a plastic sewer pipe installation must be "checked" to determine if the line has deflections which exceed a specified limit, some type of deflectometer or go/no-go gauge must be used to make such a test. A pin-type go/no-go gauge has been designed to stop at any area in a flexible underground pipeline having vertical ring deflection greater than 5 percent, the minimum deflected vertical inside diameter based on Water Pollution Control Federation (WPCF) recommended deflection limit, Manual of Practice No. 9, page 222. Dimensions are based upon information contained in the pipe manufacturer's specifications.

The pin-gauge must have free vertical movement in the sled bushing. A coating of automotive grease is recommended on that part of the pin riding in the bushing. A film of oil applied to the sled and pins will protect against corrosion.

Sewers often contain some sand or grit and the pin-gauge may experience wear after a period of time. Judgment and accuracy requirements will determine replacement.

Operation

It is important to determine that the line is free of stones or other debris before making a test. This is accomplished by pulling the sled through the line without the pin-gauge installed. If debris is evident, flushing or jetting may be necessary.

A strong cord or cable can be used to pull the go/no-go. Hand pulling is recommended to avoid jamming the gauge in a deflected

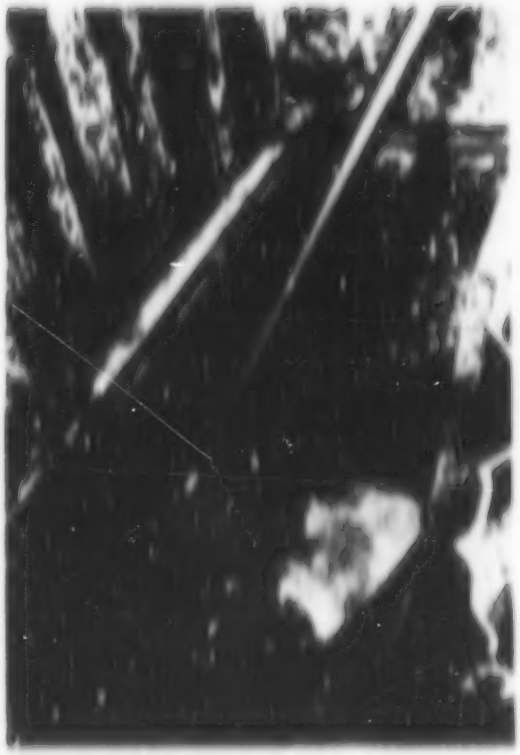
area. Light cords which could break or stretch excessively should not be used.

Suppliers of Deflection Gauge

Quality Test Products - 4400 Wildwood Drive, Crystal Lake, Illinois 60004.

Manufactures Pin-Type Go/no-go Gauge. The cost of the sled is $40.00 plus shipping. One sled accommodates all pin-gauges. Each pin-gauge is $15.00 plus shipping. State type of pipe, diameter, ASTM No. and Class when ordering.

Figure 39. A 10-in. (25.4 cm) liner being inserted into a collapsing sewer line in Baytown, Texas.



Source: Phillips Products Company, Inc., Dallas, Texas

Figure 40. Special connection at the leading end of the pipe permits the installers to pull the pipe through the old sewer.

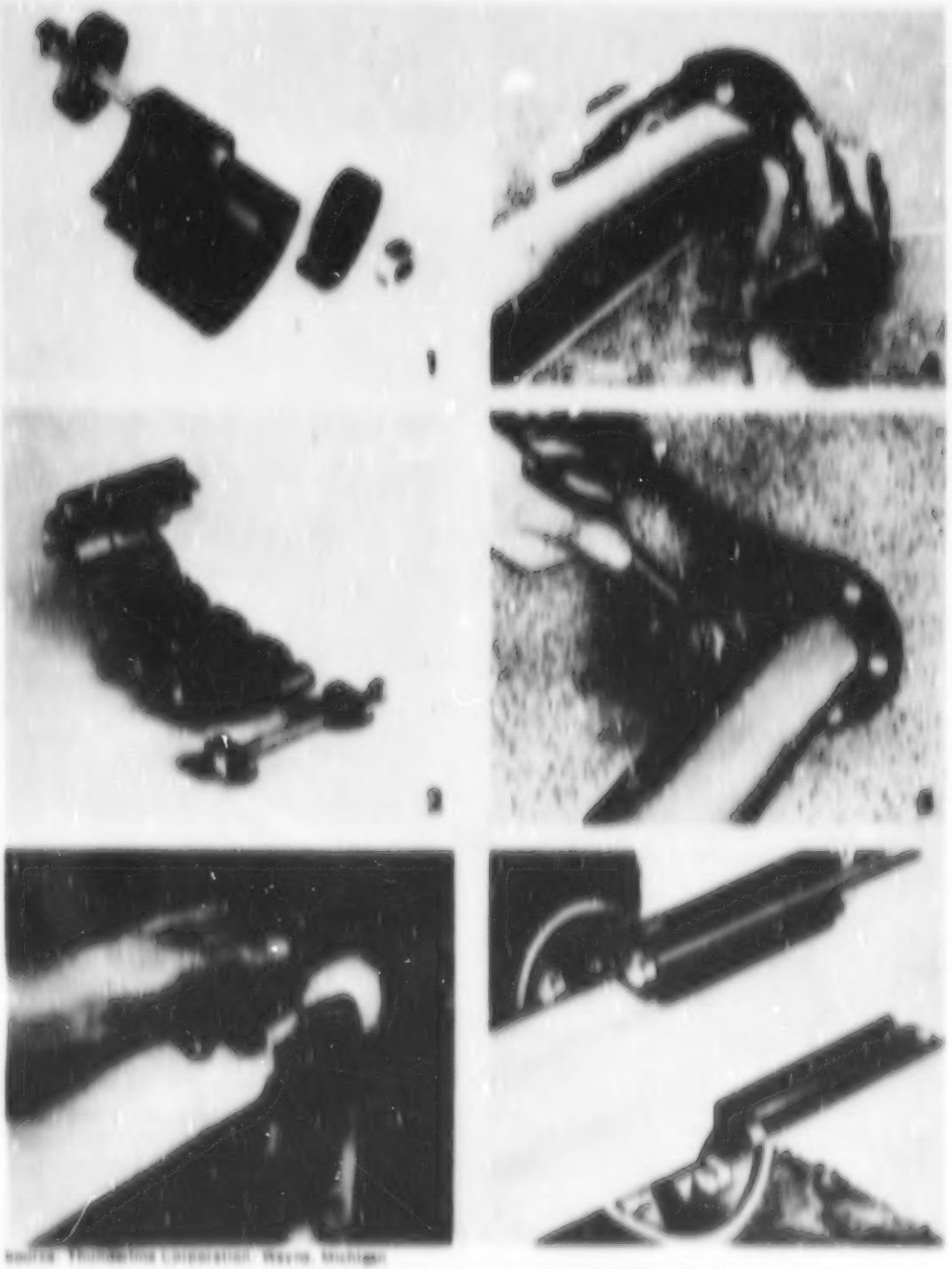
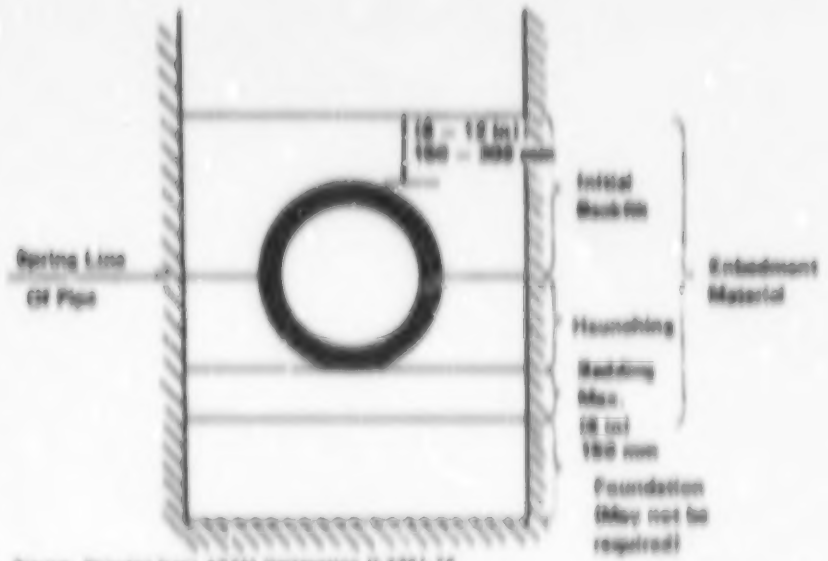


Figure 41. Sequence of operation followed when installing the Thunderline manhole connector.

Source: Industrial Pollution Control Systems, Inc.
Hudson, New Hampshire

Figure 42. The cutaway portion of the NPCS Kor-N-Seal boot designed to connect a sewer pipe to a manhole shows the internal toggle band that seals it to the manhole opening and the external clamping band that seals to the sewer pipe.



Source: Drawing from ASTM Designation D 2321-74

Figure 43. For the installation of single-wall plastic pipe, ASTM standards recommend compaction specifications to a Proctor density in the foundation, bedding, and haunching areas.

Source: Bearcat Tractor Corporation, Minocqua, Wisconsin

Figure 44. A vibrating compactor mounted on a backhoe in place of the bucket compacts a one-foot backfill lift.

Source: Seaman Nuclear Corporation, Milwaukee, Wisconsin

Figure 65. Quick soil-density determination of the compacted lift with nuclear meter.

SECTION VII

SAFETY MEASURES

High Risk Working Conditions

Work in a sewage collection system historically has generated a notoriously high injury rate. Continuing studies by the Water Pollution Control Federation (WPCF) show that collection systems account for 30 to 60 disabling injuries per million man-hours worked. This compares with a rate of about 10 for other systems.

An examination of the records strongly suggests that many systems are more injury-susceptible than others. In 1973 for example, all of the injuries occurred in less than 30 percent of the collection systems reporting to the WPCF and half occurred in less than 3 percent of the reporting systems. Since the WPCF survey is voluntary and since many systems with high injury rates would be reluctant to report, the actual injury rate is probably higher than the already high figure that the WPCF studies disclose.

Injuries and deaths related to work in collection systems can involve workers as well as motorists and pedestrians. Aside from the pain and general anguish caused by these injuries the threat of massive damage suits for negligence is always present. Failure to adhere to recognized safety standards increases the risk of liability.

Above Ground and Below Ground Safety Measures

Safety measures can be grouped roughly into (1) above-ground or street level precautions, and (2) below-ground measures in the manhole or the sewer system itself.

Both merit as much attention as the actual work and possibly more since human life is being risked.

Above Ground Protection Measures

Notification of Work

Any work on a collection system that involves activities at a manhole located in the street should begin by notifying other concerned agencies in advance. At a very minimum these agencies should include:

1. *Police Department*, especially if it has responsibility for traffic control.
2. *Fire Department*, in case fire trucks must be dispatched through the area.
3. *Traffic Engineering Division*, if separate from police.
4. *Transit Services*, including taxi companies.
5. *Water and Street Divisions*.
6. *Other public and private utilities*, such as gas, electricity, telephone, and cable television.

Probably the most authoritative guide on how to control traffic both during normal conditions and during periods of maintenance and construction will be found in the "Manual on Uniform Traffic Control Devices," (MUTCD) developed by the Federal Highway Administration, U.S. Department of Transportation. Its preparation enjoyed the active support of influential groups such as the National League of Cities, the National Association of Counties, the Institute of Traffic Engineers, and the American Association of State Highway and Transportation Officials. It also is used in legal decisions that involve negligence.

This discussion attempts to comply with its recommendations. Of use to municipal officials in urban areas is a handbook on Work Site Protection developed by the APWA and available from the U.S. Department of Transportation.

Detour Requirements

Detours around work in the street should be planned to meet at least three general specifications:

1. The motorist should receive ample advance warning. He should never be surprised.
2. The detour or bypass should be marked clearly so that the motorist will have no difficulty following it. If possible, the detour should not slow traffic by more than 10 mph (16 km/h).
3. The warnings and detours should give every consideration for the safety of the motorist, pedestrian and workers.

Warning Signs

Warning signs used for work around manholes and similar locations must have a distinctive color, different from traffic control signs. The color must be orange with black lettering, selected to call the motorists attention to unusual work on the roadway in accordance with the MUTCD or state adopted standards.

The signs must be simple so that the message can be grasped easily. They also may carry orange flags or yellow flashing lights as long as they do not interfere with the motorists' view of the sign face. If lighting is necessary, battery-operated lights should be used rather than torches or the familiar kerosene "bomb." "Bombs" can be extinguished easily by wind and can be dangerous if an accident involves a ruptured gasoline tank.

Traffic Transition Lanes

When work of this nature takes place in a street it inactivates at least one lane of traffic. This requires movement of the traffic out of the lane into whatever lane still is available.

To move traffic safely out of a lane needed for work requires use of a tapering transition lane. To determine the length of the taper multiply the width of the traffic lane by the speed limit or by the estimated speed of 85 percent of the traffic. If the speed is 40 mph (64 km/h) and if the lane width is 10 ft (3.0 m) the transition length will be 400 ft (122 m) and the transition change should be one foot per 40 ft (12.2 m) of roadway length.

To outline the changing traffic lane requires the use of traffic cones or tubes large enough to be seen easily yet sturdy enough to remain undamaged if hit by a vehicle. They should be at least 18 in. (46 cm) high, reflectorized, and colored orange. In case of high winds or traffic-induced air eddy currents, the cones can be doubled to provide extra stability or a cone with a ballastable bottom can be used.

Oil drums also can be used. These are easily visible, portable, and produce an appearance of solidity that the drivers respect. They create more damage when hit than cones. Drums should be weighted with sand or concrete to keep them from being moved by the wind or passing vehicles. Drums should be painted orange and white in horizontal strips 4 to 6 in. (10 to 15 cm) wide. They should be reflectorized if used at night and preferably equipped with flashing warning lights.

When the manhole must be opened for inspection, a class B unit high level warning sign can be quickly set up and may be more practical than setting up a wedge of traffic cones or barriers.

Flagpersons

Conditions may dictate the use of flagpersons to control the traffic if traffic is heavy enough to cause congestion or if the work requires the use of one lane on a roadway with only two lanes available. If a flagperson is required an orange vest should be worn, preferably fluorescent and reflectorized. The flagperson definitely should not be a marginal employee, but should be alert or with good sight and hearing and able to direct traffic with confidence and courtesy. If two flagpersons are needed, they may be supplied with walkie-talkie radios so that they will have better control when changing the direction of traffic.

The flagperson should be equipped with a red flag of at least 24 x 24 in. (61 x 61 cm) on a 3 ft (0.9 m) pole. The flag should be weighted for easier visibility. As a better and more understandable alternative, flaggers can be supplied with a long handled paddle with "Stop" painted on one side in white letters on a red background. An octagonal outline resembling a standard stop sign at least 18 in. (46 cm) in diameter should be used. The word "Slow" should appear on the opposite side.

Make Personal Check of Traffic Controls

In setting up the protective signs and barricades the supervisor should make a personal check of the work area, driving through it to determine that the motorist receives the needed guidance. Lights can be misleading. Signs may be blurred by background colors. Warning lights which appear well-placed may actually appear to be a maze of purposeless blinking. The supervisor's inspection can discover these trouble points and correct them.

Truck Used for Barricade

A truck that must usurp the traffic lane for use by the crew working at the street-located manhole can serve as a barricade in one direction. The truck should be amply supplied with warning lights and a rotating light on the cab roof. It also should carry a large sign reading, "Caution." The sign should be detachable so that it can be reversed, showing a blank side when going to and from work. Full signing and barricades or traffic cones are also needed in advance of the truck.

Other Barricades

The most useful type of barricade is the sawhorse, generally 6 to 8 ft (1.8 to 2.4 m) long, mounted on an A frame and a minimum of 3 ft (0.9 m) high. These customarily carry diagonal stripes at a 45° angle, alternating white and orange. If a traffic-lane change or detour is indicated, the stripes should slope downward in the direction that the traffic must travel. If traffic has its choice of moving to the right or left, then the striping should slope downward in both directions, starting from the center of the barricade. Other types of barricades also can be used. Large sawhorses as such are impractical due to their width, difficulty to store or transport, bases with reflectorized boards may be used.

Principal Suppliers of Traffic Control Equipment for Street Maintenance Operation

R. E. Dietz Company — Box 1214, Syracuse, New York 13201. Supplies a wide range of hazard lighting and safety equipment that includes: Electrically powered, trailer-mounted message and arrow boards, mini-arrow boards to be mounted on the tops of cars or trucks; a variety of metal barricades; fluorescent traffic cones, battery-powered flashing lights; reflectorized and fluorescent vests; warning flags and stop/slow paddles; and many accessories.

W. S. Darley & Company — 2030 Anson Drive, Melrose Park, Illinois 61060. Supplies barricades, traffic cones and warning lights.

Eastern Metal of Elmira, Incorporated — 1430 Sullivan Street, Elmira, New York 14901. Supplies a variety of warning signs, barricades in various sizes and types, traffic cones, flagger directional paddles and nylon fluorescent warning flags.

Electro-line Product Company — Division of Waters Instruments, Inc., P.O. Box 6117, Rochester, Minnesota 55901. Supplies flashers, electric lanterns and warning signals.

Industrial Products Company — 214 Cabot Boulevard, Langhorne, Pennsylvania 19047. Supplies warning flags and protective vests.

Grimco, Incorporated — 141 Hanley Industrial Court, St. Louis, Missouri 63114. Supplies traffic cones and lane dividers.

Lyle Signs, Incorporated — 4410 W. 78th Street, Minneapolis, Minnesota 55435. Supplies barricades in various sizes and types, flags, flagger signs, flashers, high level warning devices, a variety of warning signs and traffic cones.

Julian A. McDermott Corporation — 1641 Stephen Street, Ridgewood, Long Island, New York 11227. Supplies work-area protection barricades, heavy-duty flashers, arrow boards, vehicular warning lights, traffic cones, warning standards and flags.

Mercury Products Corporation — Miralinks Division, 336 Chapman Street, Providence, Rhode Island 02905. Provides barricades, traffic cones and other traffic-control equipment.

3 M Company — 3 M Center, St. Paul, Minnesota 55101. Supplies barricade signs and adhesive attachments for use on cones, barrels, and other equipment.

Radiator Specialty Company — 1400 West Independence Boulevard, Charlotte, North Carolina 28208. Supplies barricades, flags, flashers, warning lights and traffic cones.

Safety Flag Company of America — 190A Pine Street, Pawtucket, Rhode Island 02862. Supplies fluorescent safety flags, stop/slow paddle signs and safety wearing equipment.

Safety Guide Products — International Plastics, Incorporated, 10 Innovation Lane, Colwich, Kansas 67030. Supplies cone barricades, barricade lights, 3 ft (90 cm) traffic cones, warning flags, high level warning devices, knit and folding plastic construction signs, sign stands, rumble strips, delineator posts, vests and stop/slow paddles.

SAMS, Inc. 1160 108th Street, Grand Prairie, Texas 75050. Supplies barricades and traffic cones.

Streeter-Amet Division, Mangood Corporation, Grayslake, Illinois 60030. Supplies the Excalite flashing warning lights, rotating lights and barricades.

Toledo Pressed Steel Company, 197 Phillips Avenue, Toledo, Ohio 43612. Supplies barricades, traffic cones, flags, flashers and warning lights.

Traffic Safety Supply Company, 2324 Umatilla Street, Portland, Oregon 97202. Supplies barricades, traffic cones, flags, flashers, warning lights, portable sequential arrow signs, reflective tape, flagger hand-signal equipment, safety hats and vests.

TePed Traffic Controls, Inc. 11313 N. Broadway, Rt. 2, Oklahoma City, Oklahoma 73115. Supplies barricades, traffic cones, warning signs, and safety vests.

West Side Iron Works, Inc. 1331 Michigan Street, NE, Grand Rapids, Michigan 49503. Supplies barricades, flags, flashers and warning lights.

Below-Ground Safety Measures in Manholes and Sewers

Working conditions in and around manholes and sewers can be dangerous and demand careful attention at all times. Regardless of the task, safe work procedures should be outlined clearly and all crew members should be thoroughly familiar with them. Protective equipment should be inventoried for the workers. As a minimum, employees should be provided with:

1. Safety clothing such as "hard hats," rubber boots, safety goggles, foot protectors, and rubber gloves.
2. Safety equipment such as safety harnesses, toxic and combustible gas-detecting equipment, oxygen-deficiency detecting equipment, portable blowers, first-aid kits, rescue breathing apparatus and fire extinguishers.

The following regulations pertaining to work in confined areas are listed under the U.S. Department of Labor's Occupational Safety and Health Standards 29 CFR 1910:

- **Subpart B, Adoption and Extension of Established Federal Standards:**
  - Section 1910.12 Construction work.
  - Section 1910.13 Ship repairing.
  - Section 1910.14 Shipbuilding.
  - Section 1910.15 Shipbreaking.
- **Subpart D, Walking-Working Surfaces:**
  - Section 1910.23 Guarding floor and wall openings and holes.
  - Section 1910.25 Portable wood ladders.
  - Section 1910.26 Portable metal ladders.
  - Section 1910.27 Fixed ladders.
  - Section 1910.28 Safety requirements for scaffolding.
  - Section 1910.29 Manually propelled mobile ladder stands and scaffolds (towers).
- **Subpart E, Means of Egress:**
  - Section 1910.36 General Requirements.
  - Section 1910.37 Means of egress, general.
- **Subpart F, Powered Platforms, Manlifts, and Vehicle-Mounted Work Platforms:**
  - Section 1910.66 Power platforms for exterior building maintenance.
  - Section 1910.67 Vehicle-mounted elevating and rotating work platforms.
  - Section 1910.68 Manlifts.
- **Subpart Z, Toxic and Hazardous Substances (Formerly Subpart G) Occupational Health and Environmental Control:**
  - Section 1910.1000 Air contaminants.
  - (Plus Sections 1910.1001 through 1910.1017, dealing with specific contaminants).
- **Subpart G, Occupational Health and Environmental Control:**
  - Section 1910.94 Ventilation.
- **Subpart H, Hazardous Materials:**
  - Section 1910.101 Compressed gases (general requirements).
  - Section 1910.102 Acetylene.
  - Section 1910.103 Hydrogen.
  - Section 1910.104 Oxygen.

- Section 1910.105 Nitrous oxide.
- Section 1910.106 Flammable and combustible liquids.
- Section 1910.107 Spray finishing using flammable and combustible liquids.
- Section 1910.110 Storage and handling of liquified petroleum gases.
- Section 1910.111 Storage and handling of anydrous ammonia.

• **Subpart I, Personal Protective Equipment:**

- Section 1910.132 General requirements.
- Section 1910.133 Eye and face protection.
- Section 1910.134 Respiratory protection.
- Section 1910.135 Occupational head protection.
- Section 1910.136 Occupational foot protection.
- Section 1910.137 Electrical protective devices.

• **Subpart J, General Environmental Controls:**

- Section 1910.144 Safety color code for marking physical hazards.
- Section 1910.145 Specifications for accident prevention signs and tags.

• **Subpart K, Medical and First Aid:**

- Section 1910.151 Medical services and first aid.

• **Subpart L, Fire Protection:**

- All Sections: 1910.156 through 1910.165.

• **Subpart M, Compressed Gas and Compressed Air Equipment:**

- All Sections: 1910.166 through 1910.169.

• **Subpart P, Hand and Portable Powered Tools and Other Hand-Held Equipment:**

- Section 1910.242 Hand and portable powered tools and equipment, general.
- Section 1910.243 Guarding of portable powered tools.
- Section 1910.244 Other portable tools and equipment.

• **Subpart Q, Welding, Cutting, and Brazing:**

- Section 1910.251 Definitions.
- Section 1910.252 Welding, cutting, and brazing.

• **Subpart R, Special Industries:**

- (All pertinent Sections, 1910.261 through 1910.267a)

• **Subpart S, Electrical:**

- Section 1910.308 Application.
- Section 1910.309 National Electrical Code.

Readers also should be familiar with Part 1926, CFR Construction, as it pertains to confined areas, including tunnels, trenches and open pits.

Source: National Safety News, Feb., 1976

Safe Air Conditions

After insuring that the work area is protected from traffic hazards, and *before* the manhole cover has been removed, the supervisor should test for the oxygen and combustible gas content of the atmosphere within the manhole.

Measurements for oxygen deficiency should be made first to ascertain that sufficient oxygen is present for combustible gas testings as well as for life support. A combustible gas indicator should then be used. The instrument(s) used should be provided with a probe that can be inserted through a hole in the manhole cover. Figures 46 and 47 show typical equipment.

If the tests show safe conditions the cover may be removed, permitting the supervisor to make further tests in the lower levels of the manhole. Gasoline vapors are heavier than air and would tend to collect at the bottom. Tests should be made every 2 ft (0.6 m) from the top to the bottom of the manhole. In deep manholes, the test should confirm the presence of or absence of carbon monoxide, hydrogen sulfide and ammonia, all of them potentially lethal. Colorimetric detector tubes with appropriate sampling pumps can determine whether these hazardous gases exist in dangerous concentrations.

Ventilation of Manholes and Sewers

Any manhole greater than shoulder deep should be ventilated, whether hazardous gases are present or not. If tests detect no dangerous gases, the manhole still should be ventilated for at least one minute using a forced-draft fan capable of delivering at least 100 ft^3/min (5.7 m^3/min). The blower should have a long, flexible ventilating tube that will extend well into the manhole. The engine powering the blower should be located well away from the manhole, at least 10 ft (3 m) preferably cross wind, to prevent any explosive gases from reaching the engine and engine exhaust gases from entering the manhole.

If a breeze is present at ground level, natural ventilation can be induced by the use of metal or canvas hoods that will deflect the breeze into the manhole. This requires moderately strong breezes and the removal of adjacent manhole covers.

Safe Sewers

If the wastewater in the sewer is flowing freely and is not septic, and if the holes in the manhole covers are open so that surface air can enter, aerobic conditions probably exist and no dangerous gases will be generated. However, personnel should be trained to suspect *any* tightly covered tank, chamber or manhole, no matter what its depth. Deep tanks, pump wet well and sludge digestion tanks, all demand the utmost caution before entry.

Dangerous Sewers

In general, certain types of sewers carry a greater risk than others. Those that are especially suspect are:

1. Trunk sewers, especially those that pass through industrial areas.
2. Sewers near gas mains or gasoline storage tanks.
3. Sewers on flat grades with sluggish flow where solids may settle out and decompose anaerobically, generating methane, hydrogen sulfide and carbon monoxide.
4. Sewers with long runs, more than 300 ft (91 m) between manholes, and also those with inverted siphons.

Manhole Lighting

The safest method for illuminating the interior of a manhole is through the use of mirrors that reflect the sunlight into the manhole or sewer. For convenience, explosion-proof lights approved either by the U.S. Bureau of Mines U.L. (Class I Group D) or the U.S. Coast Guard can provide the illumination.

Entry into a Manhole

As shown in Figure 48, those entering manholes should wear "hard hats" conforming with standards set by the American National Standards Institute (ANSI) Z89.1-1969. Tools and materials should be lowered into the manhole by rope and never dropped. Small items should be lowered by bucket.

Manholes generally are equipped with steps cast into the wall. Many are not corrosion proof and therefore can be dangerous. If the steps appear unsafe, the man entering the manhole should use a strong, spark-proof ladder.

Safety Body Harness

Personnel should wear safety belts or body harnesses as shown in Figure 49 any time they enter a manhole more than shoulder deep. The belt should be of a type that will allow the worker to be lifted through the manhole opening while in a vertical position. One man should be stationed on the surface for each worker in the manhole. His sole duty should be to hold the rope and see that the man in the harness is in good shape. Another man at the surface should be available for help. Self-contained breathing apparatus should be used by anyone going to the "rescue" of a person in the manhole. Belts, harnesses and suspension systems should meet ANSI Standard A10.14 - 1975.

General Precautions

Even when atmospheric conditions in the manhole are not hazardous, precautions still are mandatory. These should be considered basic:

1. Do not smoke within a manhole or sewer.
2. Train personnel not to raise their hands above the collar to avoid the risk of allowing contamination to enter the body.
3. Wear coveralls or other removable outer garments to protect regular clothing; rubber boots or non-sparking safety shoes; and gloves, preferably rubberized, to avoid scratches and abrasions.
4. Retest the atmosphere at least every one-half hour for toxic and combustible gases and for oxygen content at regular intervals to insure continuing safety. If high temperatures and high humidity are encountered, order personnel out and check for danger limits. As indicated in the WPCF Manual of Practice No. 1,[3] a relative humidity of 80 at a temperature of 110° F (43° C) is dangerous. At these intolerable points, oxygen deficiency occurs which can cause collapse and death if the worker is not quickly removed.
5. In the case of a manhole that is off the street in a fairly remote location, insist that all safety equipment be transported to the manhole. The temptation will be strong to risk entry without safety equipment and the result unfortunately has been casualties and deaths.

Emergency Entry into Manholes

Personnel must be trained in the use of respiratory equipment for the emergency rescue of workers. Rescue personnel should be equipped with nonsparking tools, rubber footwear and safety belts as well as self-contained breathing apparatus.

The easiest equipment to use is the hose mask as shown in Figure 50. A face piece fits snugly to the face and a flexible hose leads from the mask to the source of good air. A discharge valve exhausts the respired breath. However, the size of the hose makes it difficult at times to use.

The hose mask will serve for a distance of 75 ft (22.8 m) without a blower in atmospheres not immediately hazardous to life or health and will serve for 300 ft (91 m) with a blower. *(In general, if an atmosphere is "not immediately hazardous," personnel can escape without the need for respiratory equipment.)* Also, airline respirators with half or full face piece, helmets or hoods of constant flow and pressure demand, or demand flow, can be used with as much as 300 ft (91 m) of air hose in atmospheres not immediately hazardous to life or health. When equipped with an egress cylinder rescue personnel can use this equipment in atmospheres that *are* immediately hazardous. The air supply must be at least Grade D, ANSI *Z86.1* — 1973, American National Standard Commodity Specifications for air.

Self-contained breathing apparatus should be preferred in any atmosphere that is immediately hazardous to life or health. Personnel equipped with this type of apparatus should not do strenuous work for more than a half hour.

Canister masks, gas masks or similar mechanical filter respirators should *not* be used in manholes or sewers, especially in an oxygen-deficient atmosphere. These masks will prevent entry of the particular gas for which they were designed, but cannot supply oxygen above that which is present.

For planned work rather than emergency rescue in an atmosphere not immediately hazardous, the air-supplied respirator should be preferred, especially if equipped with an egress cylinder in case atmospheres immediately hazardous should be encountered.

Table in Appendix A, drawn from the WPCF Manual of Practice, lists characteristics of dangerous gases that may be encountered in sewers, manholes, pumping stations and treatment plants.

Principal Suppliers of Equipment for Use by Personnel Working in Manholes and Sewers

Safety Harness

W. S. Darley & Company — 2000 Anson Drive, Melrose Park, Illinois 60106. Can supply three types of safety belts and harnesses. One has a safety-cable feature that limits a fall to 6 in. (15 cm) in case the access ladder fails.

Miller Equipment Division — ESB, Inc., P.O. Box 271, Franklin, Pennsylvania 16323. Manufactures a complete line of safety belts and harnesses including lifelines, lanyards,

wristlet type rescue harnesses and flexible side-rail wound or aluminum rung ladders.

Mine Safety Appliances Company - 400 Penn Center Boulevard, Pittsburgh, Pennsylvania 15235. Can supply several types of harness: manhole type, chest harness with or without leg straps, full-body harness, chest-waist harness, and wrist-type rescue harness designed to draw an injured or unconscious worker through a small opening. Three types of buckles are available: tongue, fixed bar friction and sliding-bar friction.

Ventilation Tubing

National Mine Service Company - 1000 Koppers Building, Pittsburgh, Pennsylvania 15219. Supplies Flexfab tubing made of heavyweight, 2-ply PVC-dipped nylon, reinforced with a spring-steel spiral wire. The tubing is flame resistant, made in diameters from 12 to 36 in. (30 to 91 cm) in 100 ft (3 m) lengths.

Toxic Gas Detectors
(approved by the National Institute for Occupational Safety and Health, NIOSH)

Bendix Environmental Science Division - 1400 Taylor Avenue, Baltimore, Maryland 21204. Supplies Gastec Model 400 multi-stroke sampling pump (Bendix P/N 24175335) through sales representative National Environmental Instruments, Inc., P.O. Box 590, Warwick, Rhode Island 02886. Tubes presently certified by NIOSH include those for CO, SO_2, CO_2, CCl_4, CH_4, H_2S, NO, NO_2, NH_3, Cl_2, C_2, HCl, trichloroethylene, and benzene.

Besides continuing NIOSH approvals, a complete line of gas sampling tubes are offered. All tubes are self reading. Calibration scales are printed on each tube. Tubes are $9.85 per box of 10 regardless of the type and pump kits (including spare parts package) are $75.00.

Bio Marine Industries - 45 Great Valley Center, Malvern, Pennsylvania 19355. Supplies a complete line of combustible gas and oxygen deficiency monitors. These units include portable continuous measuring oxygen analyzers and monitors with alarms and remote sensors, combustible gas detectors and combination units for combustible gas and oxygen monitoring with alarms. Remote sensors are also available. All instruments are Bureau of Mines approved.

Energetics Science, Inc. - 85 Executive Boulevard, Elmsford, New York 10523. Manufactures toxic gas analyzers capable of measuring H_2S in ranges as low as 0-10 ppm and as high as 0-5,000 ppm. The ECOLYZER H_2S Analyzers use electrochemical principals of detection and can be equipped to alarm within 30 seconds. The HIPSTER unit weighs 4 lb (1.8 kg) and costs $1,295. Calibrating accessories are an additional $200 or $250.

Matheson Gas Products - P.O. Box E, Lyndhurst, New Jersey 07071. Distributor of Kitagawa equipment. Supplies for Kitagawa model 400 aspirating pump, Matheson PN 8014-400, certified for use with appropriate tubes to detect CO, CO_2, SO_2, O, NH_3, hydrogen cyanide and 80 other chemicals not yet certified by NIOSH. Model 8014-400 Kit 590.00, Tube $8.00-$15.00.

Mine Safety Appliances Company - 400 Penn Center Boulevard, Pittsburgh, Pennsylvania 15235. Supplies Detector Tubes for CO, H_2S, CO_2, and NH_3, which have been certified by NIOSH when used with the MSA part number 83400 Universal Sampling Pumps. Tubes are also available for testing other compounds.

Narbo Industries - P.O. Box 6507, Pasadena, Texas 77506. Combination toxic, combustible and low oxygen gas detector.

National Mine Service Company - 1000 Koppers Building, Pittsburgh, Pennsylvania 15219. Supplies the National/Drager multi-gas detector composed of a hand-operated bellows pump that delivers 0.1 in.^{3} (100 cm^3) of gas with each stroke and a variety of disposable test tubes to be used with the bellows pump. Each tube has been designed to detect and measure a specific gas. Those pertinent to sewer collection systems and that have NIOSH certification include: CO, CO_2, H_2S, SO_2, toluene and trichloroethylene. The current cost of the detector is $130. A pack of ten tubes for each gas runs between $11.00 and $13.50 depending on the gas to be measured.

The company also distributes the Koehler flame safety lamp that detects and monitors oxygen deficiency and methane gas in areas

such as manholes and sewers. The lamp will burn continuously for 12 to 14 hours on one filling.

Combustible Gas and Oxygen Measuring Instruments

Bendix Environmental Science Division — 1400 Taylor Avenue, Baltimore, Maryland 21204. Supplies a Micro Methanometer (Model 18000) for the detection of combustible gasses through wires representative. National Environmental Instruments, Inc., P.O. Box 590, Pilgrim Station, Warwick, Rhode Island 02888, and Proctor/Mineco, Jones & Oliver Street, St. Albans, West Virginia 25177. The unit is approved by the U.S. Bureau of Mines 8E-29 for use in explosive atmospheres.

Bio Marine Industries — 45 Great Valley Center, Malvern, Pennsylvania 19355. Supplies a complete line of combustible gas and oxygen deficiency monitors. These units include portable continuous measuring oxygen analyzers and monitors with alarms and remote sensors, combustible gas detectors and combination units for combustible gas and oxygen monitoring with alarms. Remote sensors are also available. All instruments are Bureau of Mines approved.

Mine Safety Appliances Company — 400 Penn Center Boulevard, Pittsburgh, Pennsylvania 15235. Supplies detector tubes for carbon monoxide, hydrogen sulfide, carbon dioxide, ammonia, nitrogen dioxide, chlorine and sulfur dioxide, acetone, and trichloroethylene. As of March 1, 1976, these tubes have been certified by NIOSH when used with the MSA P/N 91499 Universal Sampling Pump. Tubes for approximately 120 other compounds, not yet certified by NIOSH, can be used with the 83499 Universal Pump.

Self Contained Breathing Apparatus, NIOSH Approved

Bio Marine Industries — 45 Great Valley Center, Malvern, Pennsylvania 19355. Supplies a 45 minute self-contained breathing apparatus weighing only 17 lbs (7.7 kg) with a chest mounted closed circuit system. NIOSH, MSA, and Coast Guard approved under latest schedules — TC-13F-27.

Globe Safety Products, Inc. — 125 Sunrise Place, Dayton, Ohio 45407. Supplies four models of half-hour, compressed-air, demand-type units.

Mine Safety Appliances Company — 400 Penn Center Boulevard, Pittsburgh, Pennsylvania 15235. Supplies two models of one-quarter and one-half hour compressed-air, demand-type breathing apparatus. Also has pressure-demand types as well as combination hose-line and self-contained units.

Scott Aviation — Division of ATO, Inc., Lancaster, New York 14066. Supplies two models of half-hour and two of quarter-hour compressed-air, demand-type breathing apparatus. Also, pressure-demand types, and positive-pressure units, self-contained, as well as combination hose-line and self-contained units.

SurvivAir Division — of U.S. Divers Company, 1333 W. Warner Avenue, Santa Ana, California 92702. Supplies two models of half-hour compressed-air, demand-type units.

Supplied-Air Respirators

Mine Safety Appliances Company — 400 Penn Center Boulevard, Pittsburgh, Pennsylvania 15235. Constant-flow and demand-type airline respirators and hose masks without blower.

Minnesota Mining and Manufacturing Company — (3 M), 3 M Center, St. Paul, Minnesota 55101. Can supply several models consisting of helmet, air-regulating valve and breathing-tube assembly, Vortex cooling and Vortemp heating and air-supply hose of varying lengths.

Scott Aviation — Division of ATO, Inc., Lancaster, New York 14066. Supplies demand, constant flow and positive pressure models with harness, face piece and hose-line lengths to 250 ft (76 m).

SurvivAir Division — U.S. Divers Company, 1333 W. Warner Avenue, Santa Ana, California 92702. Can supply four models consisting of face piece and regulator assembly, waist belt, and air-line hose of varying lengths.

United States Safety Service — Parmalee Industries, Inc., P.O. Box 1237, Kansas City, Missouri 64141. Respirator consists of hood

assembly, breathing tube assembly, air supply hose assembly, a quick disconnect and a body harness.

Explosion-Proof Hand Lights

Julian A. McDermott Corporation, 1639 Stephen Street, Brooklyn, New York 11227. Corrosion proof high impact plastic cases with adjustable head.

Source: Mine Safety Appliance Company, Pittsburgh, Pennsylvania

Figure 46. This oxygen indicator has been designed to test atmosphere in manholes, sewers, and similar locations.

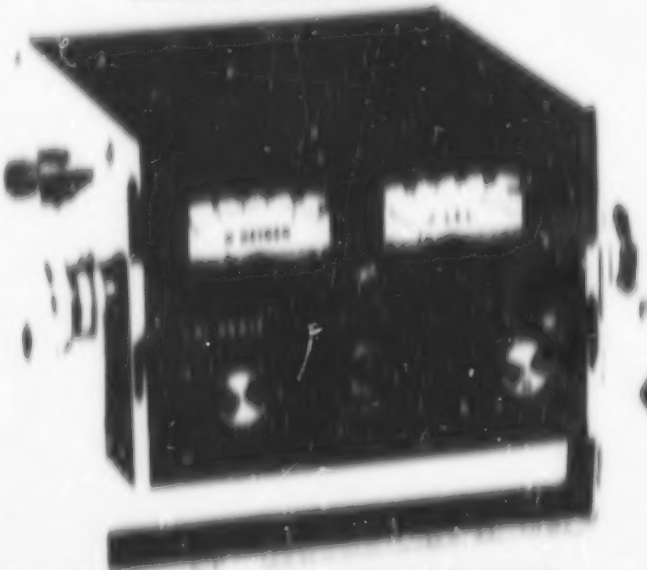


Figure 47. The portable indicator when equipped with a suitable probe and charging cable, can detect both oxygen deficiency and the presence of combustible gas.

Source: Mine Safety Appliance Company, Pittsburgh, Pennsylvania

Source: Scott Aviation, Division of ATO, Inc., Lancaster, New York

Figure 48. Rescue personnel equipped with a supplied air respirator egress emergency air supply, safety harness, hard hat and gloves.

Source: Mine Safety Appliances Company, Pittsburgh, Pennsylvania

Figure 49. A wrist harness can be used to rescue unconscious personnel. The harness brings the arms together overhead and allows the victim to be lifted out of closed structures with small openings.

Source: Mine Safety Appliances Company, Pittsburgh, Pennsylvania

Figure 50. The Constant Flow Air Line Respirator allows personnel to work in toxic atmosphere not immediately hazardous to life or health.

SECTION VIII

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APPENDIX A
CHARACTERISTICS OF DANGEROUS GASES ENCOUNTERED IN SEWERS, SEWAGE PUMPING STATIONS, AND SEWAGE TREATMENT PLANTS